DELAY OF GRATIFICATION ACROSS THE LIFESPAN: PSYCHOLOGICAL PROCESSES, NEURAL SUBSTRATES, AND CLINICAL IMPLICATIONS

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The ability to discipline yourself to delay gratification in the short term in order to enjoy greater rewards in the long term is the indispensable prerequisite for success.

(Maxwell Maltz)

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ABSTRACT

Delay of gratification (DoG) refers to an individual's ability to postpone immediate, smaller rewards in favor of later, better rewards; for example, to resist the temptation of sweets when dieting or saving money for the future. Delay Discounting (DD) is an individual's subjective devaluation of a reward whose receipt is delayed. Studies in DoG are crucial, as high DoG is a basis for individual, societal, and economic functioning across the lifespan.

This cumulative thesis takes a comprehensive approach to the exploration of DoG. Paper 1, a review, summarizes the theoretical background to DoG, placing a particular focus on DoG in adulthood and in old age. Paper 2 investigates interactions of variables (cognitive abilities, education, and personality traits) in 5- and 6-year old children's DoG and their mother's DD, drawing on data from the German Socio-Economic Panel (SOEP) children's study. Paper 3 uses structural magnetic resonance imaging (sMRI) to examine whether structural brain differences exist between elderly individuals with low and high DoG (aged between 63 and 93 years). This sMRI study used the recently validated and published Delay of Gratification Test for Adults (DoG-A; Forstmeier, Drobetz, & Maercker, 2011) which requires decisions between immediate and delayed rewards on the behavioral level.

The main findings of the thesis are as follows: Children with higher verbal intelligence and higher prosocial behavior/higher agreeableness had higher DoG (Paper 2). Higher education and lower agreeableness interacted in predicting lower DD in mothers. Elderly individuals with high DoG showed significantly increased cortical thickness in bilateral dorsolateral prefrontal cortex regions and in the left

anterior cingulate cortex as well as significantly larger gray matter volumes when compared with non-delayers.

The General Discussion of this thesis draws on all three papers to address the following general research issues: First, it clarifies whether DoG is a domain-specific, multidimensional, and stable construct and whether DoG and DD are distinct concepts. Second, DoG measurement is discussed from the perspectives of behavioral experiments versus self-report questionnaires, dichotomous versus continuous measurement, and primary versus secondary rewards. Third, the General Discussion considers the relationship between DoG and verbal intelligence, neural substrates of DoG, and DoG across the lifespan. Finally, the thesis offers an outlook on future research and outlines implications for research and clinical practice.

ZUSAMMENFASSUNG

Belohnungsaufschub (BA) wird als Fähigkeit definiert, eine unmittelbar verfügbare, geringere zugunsten von einer späteren, besseren Belohnung aufzuschieben, wie der Verzicht auf Süßigkeiten im Rahmen einer Diät oder das Sparen von Geld für zukünftige Ausgaben. Delay Discounting (DD), ein ähnliches Konstrukt, bezieht sich auf die subjektive Abwertung zukünftiger Belohnungen mit zunehmender Verzögerungszeit bis zum Erhalt. Studien zu BA sind deshalb von höchster Relevanz, weil hoher BA eine wesentliche Grundlage für individuelles, soziales und ökonomisches Funktionieren im Verlauf der Lebensspanne ist.

Das Hauptziel der vorliegenden kumulativen Dissertation war es, BA in einem umfassenden Ansatz zu untersuchen. Der erste Artikel (Paper 1), ein Review, fasste den theoretischen Hintergrund zusammen und fokussierte auf den Forschungsstand von BA bei Erwachsenen und älteren Menschen. Der zweite Artikel (Paper 2) analysierte Daten des Sozio-oekonomischen Panel (SOEP) des Deutschen Instituts für Wirtschaftsforschung (DIW Berlin). Dabei wurden Interaktionen von Variablen (kognitive Fähigkeiten, Bildung und Persönlichkeitseigenschaften) bezüglich BA bei 5- und 6-jährigen Kindern und DD von deren Müttern untersucht. Der dritte Artikel (Paper 3), eine strukturelle Magnetresonanztomographiestudie (sMRI), explorierte potentielle Unterschiede auf neuronaler Ebene zwischen Personen im Alter zwischen 63 und 93 Jahren mit hohem versus niedrigem BA. Im Rahmen der sMRI-Studie wurde BA auf Verhaltensebene experimentell mit dem validierten und publizierten Belohnungsaufschub-Test für Erwachsene (BAT-E; Forstmeier, Drobetz, & Maercker, 2011) gemessen, bei dem sich TeilnehmerInnen zwischen unmittelbaren und verzögerten Belohnungen entscheiden müssen.

Die Hauptergebnisse der Doktorarbeit: Kinder mit einer höheren verbalen Intelligenz und mit einem höherem prosozialem Verhalten / mit einer höheren Verträglichkeit zeigten höheren BA. Höhere Bildung und geringere Verträglichkeit interagierten hingegen bei den Müttern bezüglich niedrigem DD. Ältere StudienteilnehmerInnen mit hohem BA zeigten im Vergleich zu Personen mit niedrigem BA eine grössere kortikale Dicke im rechten dorsolateralen Präfrontalkortex sowie im linken anterioren Gyrus und Sulcus cingulus. In subkortikalen Strukturen fand sich ein grösseres Volumen bei Personen mit hohem BA in Strukturen des Striatums (Nucleus caudatus und Nucleus accumbens).

In der Diskussion werden die Ergebnisse der drei Artikel miteinander verglichen. Folgende übergreifende Forschungsfragen stehen dabei im Mittelpunkt: Zunächst werden die Aspekte beleuchtet, ob BA ein domänenabhängiges, multidimensionales und stabiles Konstrukt ist und ob BA und DD unterschiedliche Konzepte sind. Die Messung von BA wird unter den Gesichtspunkten von Selbsteinschätzungsfragebögen versus Verhaltensexperimenten, dichotome versus kontinuierliche Paradigmen und Primär- versus Sekundärverstärker diskutiert. Danach wird auf die Beziehung zwischen BA und verbaler Intelligenz, die neuralen BA-Substrate sowie BA im Verlauf der Lebensspanne eingegangen. Die Dissertation schliesst mit einem Ausblick auf zukünftige Untersuchungen und bietet Implikationen für die Forschung und klinische Praxis.

INTRODUCTION

Aesop's well-known fable "The Grasshopper and the Ant," which has been the subject of countless adaptations, describes a type of decision facing humans on a daily basis: The grasshopper spends the summer living in the moment, chirping and hopping about without caring about the future, while the hard-working and foresighted ant stores food for the winter. To cut a long story short, the ant prepares for the days of necessity and postpones gratification to bad times. In scientific terms, delay of gratification (DoG) refers to the postponement of immediate and smaller rewards in favor of later and better rewards (Mischel, Shoda, & Rodriguez, 1989). Delay Discounting (DD), a similar construct, reflects the degree to which the subjective value of a reinforcer (reward or commodity) decreases as a function of time to its delivery. Indeed, the value of a reward—and hence the likelihood of its sustained choice—is known to decrease with increasing delay interval. In other words, the preference for smaller, but immediate rewards tends to increase with increasing delay. Note that high DoG means low DD. Patterns of DD are best described by the hyperbolic function (Reynolds, de Wit, & Richards, 2002).

The umbrella term "reinforcers" covers both primary rewards such as food, water, or sexual stimuli and secondary rewards such as money or cultural goods. Rewards serve primarily as goals for voluntary individual behavior (Stern, 2006). Primary rewards reinforce behavior without being learned and have intrinsic utility. As they enable survival and reproduction, they are evolutionarily innate and indispensable. Secondary rewards, in contrast, require learning-mediated processes; they reinforce behavior only after becoming associated with primary rewards. It is possible to convert secondary to primary rewards; for example, to buy food with money (Colman, Hardy, Albert, Raffaelli, & Crockett, 2006; Walter, Abler, Ciaramidaro, & Erk, 2005).

There is a general lack of DoG research, especially with respect to primary rewards, in adulthood and in old age. Inasmuch as people are confronted with DoG decisions almost every day of their lives, this may seem surprising. Not only children and adolescents have to choose between immediate and delayed gratification, adults and the elderly also have to make daily choices on whether or not to delay rewards. From the perspective of lifespan psychology, there are various practical examples of DoG: working for decades to finance a comfortable retirement, saving money for the future, or saving to leave one's children an inheritance rather than spending one's money on impulse buys. From the perspective of health psychology, DoG also plays a decisive role in health behaviors. For example, older adults may choose to take regular exercise in order to prevent or to reduce physical problems. Smokers may want to quit the habit to avoid its negative long-term effects. Adults may resist unhealthy foods, such as high-calorie sweets, in order to lose weight or abstain from excessive sunbathing in order to reduce the risk of skin cancer in later life.

Walter Mischel, an Austrian-born psychologist whose family fled to the United States during the Nazi regime, and his colleagues began their pioneering DoG experiments with children in the 1960s (Mischel et al., 2011). Since then, the construct of DoG and its long-term outcomes have fascinated psychology and allied disciplines. In Mischel's classic DoG paradigm, the experimenters leave a child—typically aged between 4 and 6 years—alone with a treat such as a marshmallow or a cookie on a table in front of him or her (Mischel, 1974). If the child calls for the experimenters or rings a bell, they come back into the room and the child is allowed to eat the marshmallow. If, however, the child waits for the experimenters to come back of their own accord (after approximately 20 minutes), the child receives two marshmallows. Mischel and colleagues specifically designed the “marshmallow test” for children (Mischel et al., 2011), and measurement of DoG in adults obviously requires adaption of this paradigm (Forstmeier, Drobetz, & Maercker, 2011).

This cumulative thesis integrating three papers (labeled Papers 1, 2, and 3) addresses DoG across the lifespan, focusing on psychological processes, neural substrates, and clinical implications.

The *Theoretical and Methodological Background* section discusses the importance of DoG and the relevance of neuroscientific studies in DoG research. Further, it summarizes the nomological network of DoG and relates DoG to the model of selection, optimization, and compensation (Freund & Baltes, 1998). Both the “gummy bear experiment” and the Delay of Gratification Test for Adults (DoG-A; Forstmeier et al., 2011) are presented: Paper 1 outlines the DoG-A, Paper 2 uses the “gummy bear experiment” and mentions the DoG-A in the Discussion, and Paper 3 uses the DoG-A to measure DoG on the behavioral level. The *Present Thesis* section summarizes all three papers, which are then brought together in the *General Discussion*, the six main subsections of which draw on all three papers: This final section seeks to determine, first, whether DoG is a domain-specific, multidimensional, and stable construct and, second, whether DoG and DD are distinct concepts. Third, it provides a comprehensive discussion of DoG measurement. Fourth, it elaborates on the link between DoG and verbal intelligence. Fifth, neural substrates of DoG are summarized. Sixth, the *General Discussion* closes by considering the contribution of this thesis to research on DoG across the lifespan. Finally, the *Implications* section offers an outlook on future research and outlines implications for research and clinical practice.

THEORETICAL AND METHODOLOGICAL BACKGROUND

Importance of Delay of Gratification

Why is individuals' ability to postpone immediate, smaller rewards in favor of delayed, larger rewards so important? And why is there a need for DoG research across the lifespan?

DoG is not only highly relevant on the individual level—it also impacts society as a whole (Wulfert, Block, Santa Ana, Rodriguez, & Colsman, 2002). Indeed, "resisting temptation in favor of long-term goals is important for individual, societal, and economic functioning" (p. 15001; Casey et al., 2011).

Deficits in DD are associated with problematic behaviors such as violence and crime (Baumeister & Heatherton, 1996; Cherek, Moeller, Dougherty, & Rhoades, 1997), substance abuse (Baumeister & Heatherton, 1996; Madden, Petry, Badger, & Bickel, 1997), and internet addiction (Saville, Gisbert, Kopp, & Telesco, 2010). Baumeister and Heatherton (1996) argued that social problems such as teen pregnancies and gambling are also consequences of DoG failure. Indeed, studies have shown higher DD in individuals with pathological gambling (e.g., Andrade & Petry, 2012; Stea, Hodgins, & Lambert, 2011) as well as in individuals with antisocial personality disorders or psychopathy (Morgan, Gray, & Snowden, 2011; Petry, 2002). Additionally, studies have reported lower DoG/higher DD in children and adults with obesity (Appelhans et al., 2011; Bonato & Boland, 1983; Weller, Cook, Avsar, & Cox, 2008), prevalence rates of which are increasing dramatically in wealthy countries and in affluent cohorts of developing and threshold countries (Tim, 2011). In fact, low DoG in 4-year-old children predicts overweight at the age of 11 (Seeyave et al., 2009).

Whereas low DoG is a risk factor for adverse outcomes, high DoG is associated with benefits or positive side effects, such as better cognitive, motivational, and social functioning across the lifespan (in childhood, adolescence, and adulthood) and higher cognitive control, inhibition, attentional control, ego-control, intelligence, educational achievement, prosocial behavior, self-worth, and coping with stress (Ayduk et al., 2000; Eigsti et al., 2006; Mischel, 1961b, 1974; Mischel & Metzner, 1962; Mischel, Shoda, & Peake, 1988; Shoda, Mischel, & Peake, 1990). Additionally, high DoG in the academic context (academic DoG) is linked to better academic performance (Bembenutty & Karabenick, 1998).

In older adults aged between 60 and 94 years, the ability to delay gratification for primary reinforcers (snacks) has been shown to be significantly positively correlated with self-reported satisfaction with life, motivation regulation, optimism, and facets of conscientiousness. Conversely, DoG proved to be significantly negatively correlated with depressive symptoms, anxiety, negative affect, hostility, and perceived stress. Further, DoG was a significant predictor of wellbeing, even when diverse confounding variables were controlled (Forstmeier et al., 2011).

Relevance of Neuroscientific Studies in Delay of Gratification Research

Various studies have investigated the relevant neural substrates and activation patterns in DD and impulsivity (see Paper 3). However, the neural mechanisms underlying influencing factors, such as valuation of rewards in DD decisions, remain unclear (Peters & Büchel, 2011). Paper 3 presents a structural magnetic resonance imaging (sMRI) study of the specific behavioral construct of DoG.

Imaging studies on DoG in old age are highly relevant, as high DoG is a significant predictor of wellbeing in the elderly (Forstmeier et al., 2011). Once possible neural substrates of DoG have been detected, further studies could explore the impact of DoG training on the neural level—for example, whether specific cortical and subcortical regions increase in thickness with DoG enhancement. Imaging studies in DoG/DD may also serve as a basis for novel interventions suitable for individuals with impulse control disorders (Peters & Büchel, 2011).

Nomological Network of Delay of Gratification

DoG has been localized in the nomological network of the related constructs of DD, impulsivity, executive function, and self-regulation. In the literature, DoG, DD, and self-regulation have often been used synonymously or interchangeably (e.g., Funder & Block, 1989; Mischel et al., 1989). However, despite some overlap between the three constructs, it is important to appreciate their subtle distinctions, as differences do exist (Hoerger, Quirk, & Weed, 2011; Reynolds, Richards, & de Wit, 2006). The DoG paradigm was originally used in studies on the development of children's self-regulation (Demetriou, 2000).

Definitions of impulsivity generally state that impulsive individuals initiate behavior without sufficient reflection or forethought as to its consequences (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001). According to the reward-discounting model, impulsivity reflects the tendency to choose immediately available over delayed rewards (Monterosso & Ainslie, 1999).

DoG has also been associated with executive functions (Carlson, 2005)—that is, complex functions and skills that "enable a person to engage successfully in purposeful, self-serving behaviors" (Lezak, 1995). For example, executive functions enable goal-directed problem solving (Hongwanishkul, Happaney, Lee, & Zelazo, 2005), decision making, maintaining of action, and self-regulation (Baumeister, 1998).

The multifaceted concept of self-regulation covers internal and/or transactional processes enabling individuals to maintain goal-directed activities (Baumeister & Heatherton, 1996). In other words, self-regulation is humans' capacity to alter their own responses (Baumeister, Vohs, & Tice, 2007). Strong relations exist between DoG, self-regulation, and goals:

First, DoG is an aspect of self-regulation (Freund & Riediger, 2003). Successful DoG depends on successful self-regulation: Delaying individuals have to prevent themselves from thinking about immediately available rewards (Mischel, 1974). Failure of self-regulation (i.e., failure to resist temptation and therefore to postpone rewards) tends to be accompanied by an attentional shift to the immediate reward (Karniol & Miller, 1983). In a similar vein, there is a strong relationship between academic DoG and self-regulated learning strategies (Bembenutty & Karabenick, 2004).

Second, goal pursuit can result in DoG (Mischel, Cantor, & Feldman, 1996). According to Emmons's (1996) definition of goals, delayers seek to obtain the desired larger, delayed reward—and have to resist the temptation of the immediately available reward to this end.

Third, Carver and Scheier (1999) postulated that a crucial function of goals is their self-regulatory function. Put differently, self-regulation depends on clear goals, as the capacity to regulate one's behavior decreases as long-term goals fade out of the focus of attention (Baumeister & Heatherton, 1996).

Fourth, self-regulation processes influence the selection of goals as well as goal-specific behavior, such as the initiation and execution of goals (Freund, 2001). Goal pursuit in the context of DoG may cover goal setting (rejection of the immediate reward and choice of the delayed reward) and goal implementation (successful goal pursuit or postponement of a delayed reward via diverse processes and mechanisms) following the definition of goal striving (Bargh, Gollwitzer, & Oettingen, 2010).

Although DoG, self-regulation, and goals are linked, two important aspects have to be emphasized: First, individuals may differ in their attitude to a delayed reward. Whereas delayers may focus on the positive outcome pursued (i.e., the later better reward), non-delayers may see a delay (waiting time) as a negative outcome to be avoided (Higgins, 1996). Second, studies have shown that, relative to younger individuals, older adults focus more on the process ("the path is the goal") than on the outcome of a goal (Freund, Hennecke, & Riediger, 2008).

Delay of Gratification and the Model of Selection, Optimization, and Compensation

This section relates DoG to the well-established model of selection, optimization, and compensation (SOC model; Freund & Baltes, 1998). The SOC model is a meta-model of successful aging that—like DoG decisions—is relevant across the whole lifespan (Freund & Riediger, 2003). Successful aging means maintaining a level of functioning that enables older adults to successfully pursue goals and to maintain standards (Freund, 2008). Further, successful aging can be seen as a result of the effective management of internal and external resources (dynamic interaction of an individual with the environment; (Freund, 2008; Freund & Riediger, 2003). Selection, optimization, and compensation interact in successful development and aging. From an action-theoretical perspective, aging individuals need to set, pursue, and maintain goals in the face of loss and decline (Freund, 2008).

Selection describes the focus on specific goals in response to limits in resources such as time and to constraints such as functional decline (Freund, 2008;

Freund & Baltes, 1998). Optimization is “the allocation and refinement of internal or external resources as means of achieving higher levels of functioning in selected domains (goals)” (p. 531, Freund & Baltes, 1998). As older individuals are faced with depleting resources, they need to set new goals or to activate unused resources (Freund, 2008). Compensation refers to the investment of resources (i.e., substitutive processes) to maintain the level of functioning in a specific domain. Specifically, individuals facing a loss of resources or a decline in goal-related means can counteract these losses by means of compensation (Freund & Baltes, 1998). Thus, older adults have to manage losses and to maintain functioning (Freund, 1998).

DoG relates to the SOC model and DoG in various ways:

First, individuals may select personal DoG goals that ensure a fit between their resources and their needs—this is a key process of selection (Freund, 2008).

Second, DoG is seen as a general process in the context of optimization. The pursuit of long-term goals requires investment of resources and effort without immediate gains and pleasures (e.g., working on a PhD thesis rather partying with one’s friends). Resisting the temptation of immediate gratification (e.g., having fun at parties, drinking alcohol, socializing with friends, getting to know new people) is a precondition for the consistent pursuit of goals over extended time periods (e.g., getting a PhD after several years; (Freund & Riediger, 2003, 2006).

Third, aspects of self-regulation such as control beliefs, practice, and DoG are crucial for older individuals’ acquisition and investment of compensatory means in compensation processes (Freund & Riediger, 2003).

The following practical example serves to illustrate DoG in the context of the SOC model (Freund & Baltes, 1998)—and a focus on the process rather than on the outcome of a goal (Freund et al., 2008): Imagine a 70-year-old woman with osteoporosis. Although she has previously avoided sports and exercise, she now sets herself the goal of becoming physically active. During selection, she might choose an osteoporosis exercise program for older adults rather than, for example, yoga or Pilates because she wants to train with other people of her age. As she cannot expect to see an immediate improvement in her health condition, she tries to focus on the process of attending class regularly each week and making her training as enjoyable as possible. She optimizes her training program by doing additional exercises at home and compensates for exercises that she is unable to do by doing more repeats of less difficult exercises.

The Gummy Bear Experiment

Traditionally, DoG has been measured using marshmallows (Goleman, 1995; Mischel et al., 2011). The value of a reward has a meaningful influence on DoG decisions (Mischel, 1974); it must be attractive enough to motivate participants (e.g., Wulfert et al., 2002). Marshmallows are rather unfamiliar sweets in the German-speaking countries. Moreover, it seems doubtful that the choice of one marshmallow now versus two marshmallows later is an attractive enough reward for today's children. The Socio-Economic Panel (SOEP) children's study therefore used packs of (organic) gummy bears, which are common sweets in Germany, in its modified version of the classic "marshmallow test" (Goleman, 1995; Mischel et al., 2011).

In this study, the experimenter presented each participating child with one opened and one unopened pack of gummy bears and told him/her that he/she would get both packs if he/she waited until an ongoing interview with his/her mother was completed (no information was given about how long the interview would take). The children were told that if they wanted to eat gummy bears during the interview, they could help themselves from the open pack, but that they would not get a second, unopened pack of gummy bears afterwards.

Whereas gummy bears provide adequate measures of DoG in children, studies in adults and in the elderly have to adapt the classic "marshmallow test" further (see Paper 1 and Forstmeier et al., 2011). The next section presents a DoG measure for these age groups.

The Delay of Gratification Test for Adults

The Delay of Gratification Test for Adults (DoG-A; Forstmeier et al., 2011) is a published and validated behavioral measure of DoG for all age groups of adults. Specifically, the DoG-A enables the experimental measurement of self-motivation in the context of a board game. Participant and experimenter take turns in moving a counter through the streets of a fictitious city. As the rewards offered should be meaningful and attractive (e.g., Wulfert et al., 2002), participants are invited to choose their preferred snacks and magazines from a wide range of possibilities prior to the game.

Before the game begins, the experimenter explains the rules. To conceal the true aim of the test, he or she tells participants that the game is intended to measure their individual preferences and interests. As such, participants can choose whatever they want—there are no right or wrong answers. At each field on the board, the player draws a card and is prompted to make a decision. There are generally two separate sets of cards, one for the participant and one for the experimenter. The cards drawn by the participants are filler items that are not analyzed. For example, the participant has to decide which product he or she prefers: *"Imagine you are in a clothes store. Would* *you rather buy a black or a red pullover?"* Whenever the experimenter draws a card, he or she offers the participant one of four different kinds of rewards:

1. Food (sweets, salty snacks), e.g., 1 piece of chocolate (or 1 apple chip, etc.) now or 2 pieces in 2 hours (8 items).
2. Hypothetical money, e.g., *"Imagine that a friend of yours has won some money in the lottery. He or she wants to give you some money as a present. But you have to choose between CHF 6 now or CHF 10 in one month. Which would you prefer?"* (8 items).
3. Real money: CHF 8 now or CHF 10 in one month (1 item).
4. Magazines: 1 magazine now or 2 magazines in one month (1 item).

In total, participants make 18 choices between immediate, smaller and delayed, larger primary (snacks) and secondary rewards (hypothetical money, real money, and magazines). The subscores for the snacks and hypothetical money subscales range from 0 (all rewards immediate) to 8 (all rewards delayed), whereas the real money and magazines subscores are dichotomous (immediate versus delayed). To generate the DoG-A composite score, the two continuous variables (i.e., snacks and hypothetical money) are dichotomized and all four subscores are then summed. After the DoG-A game, the participant answers questions allow for the control of confounding variables (e.g., *"When did you have your last meal?"* and *"How pleasant/unpleasant was the money present for you?"*).

A validation study of the DoG-A showed that the intercorrelations of the four subscales were low to medium, indicating relative domain independence of the different reward types (Please see the General Discussion and e.g., Chapman, 1996). The internal consistency (Cronbach's $\alpha = .39$) of the composite score was moderate, and findings on the measure's criterion validity strongly supported the experimental operationalization of the DoG-A. Specifically, the DoG-A composite score correlated significantly with the general DD rate (r = -.43, $p < .05$) as well as with motivation regulation, a DoG-related concept (r = .20, $p < .05$; (Forstmeier et al., 2011).

THE PRESENT THESIS

As described in the *Theoretical and Methodological Background* section, high DoG is crucial across the lifespan. Studies examining DoG in different age groups are therefore of highest relevance. The main aim of this thesis was to explore DoG from the perspective of clinical and developmental lifespan psychology. One common thread linking the three papers presented in this thesis is that they investigate DoG in different age groups.

Paper 1, a review, examined the theoretical background to DoG, placing a particular focus on DoG in adulthood and old age. Paper 2, which focused on DoG in childhood and DD in adulthood, explored interactions of variables (cognitive abilities, education, and personality traits) impacting children's DoG and their mother's DD. The DoG-A (Forstmeier et al., 2011) is a validated measure of DoG on the behavioral level. Paper 3 went a step further and applied the DoG-A in an sMRI study. In particular, it sought to determine whether there were structural brain differences between elderly individuals with low and high DoG. This thesis thus covers three age groups and spans the whole lifespan: childhood (Papers 1 and 2), adulthood (Papers 1 and 2), and old age (Paper 3).

Specifically, the present thesis focuses on the following research questions:

Paper 1: Delay of gratification in old age: Assessment, age-related effects, and clinical implications (Drobetz, Maercker, & Forstmeier, 2012)

What is the theoretical basis of DoG?

- How is DoG linked to related constructs?
- What are traditional and novel measures of DoG?
- Why is there a lack of DoG studies in elderly populations?

- Are there age-related differences in DoG across the lifespan?
- Which clinical implications can be drawn from the evidence?

Paper 2: Interactions of cognition, education, and personality in decisions between immediate and delayed rewards in mothers and their children (Drobetz, Maercker, Spiess, Wagner, & Forstmeier, submitted)

Do cognitive abilities, education, and personality traits interact in shaping DoG and DD decisions?

- Do cognitive abilities and educational variables moderate the relationship between personality variables and DoG/DD?
- Does the strength of association between fluid and verbal intelligence and DoG/DD differ?

Paper 3: Structural brain differences between elderly individuals with high versus low delay of gratification (Drobetz, Hänggi, Maercker, Kaufmann, Jäncke, & Forstmeier, submitted)

Are there structural brain differences between elderly individuals with high versus low DoG?

- Do delayers have increased cortical thickness in prefrontal cortex areas?
- Do delayers and non-delayers show volumetric differences in subcortical structures associated with the reward system (e.g., the striatum and nucleus accumbens)?
- Are clusters of cortical thickness differences larger when DoG involves primary reinforcers than when it involves secondary reinforcers?

Note also that all three papers explored whether or not DoG and DD are distinct constructs. The next three sections summarize the main findings of each paper and answer the questions specified above.

Summary of Paper 1: Delay of Gratification in Old Age: Assessment, Age-Related Effects, and Clinical Implications

This review focused on the theoretical status of DoG—that is, its relations to and distinctions from other constructs such as self-regulation, DD, and executive functions. Further, it presented traditional and novel DoG measures (see Table 1) and discussed effects of DoG on development and wellbeing (see Table 1), as well as age-related differences in DoG. Finally, it drew conclusions, outlined clinical implications, and provided an outlook on future research.

The major reason for the scarcity of DoG studies in adults and in the elderly is the lack of appropriate measures of DoG in the form of adaptations of Mischel's "marshmallow test" for these age groups (Goleman, 1995; Mischel et al., 2011). Instead, studies in self-regulation across the lifespan have commonly used real and hypothetical DD tasks as well as various self-report measures.

With respect to age-related differences, theory and findings generally suggest a curvilinear relationship between DD and age: Children, young adults, and older adults tend to have higher DD rates than do middle-aged adults. DD is higher in early life because individuals faced with an uncertain future have to explore their environment. It increases again in later life when capacities decline and the future again turns out to be connected with risks and uncertainty (Read & Read, 2004; Sozou & Seymour, 2003; Trostel & Taylor, 2001). However, a recent study investigating age differences in DD with respect to hypothetical monetary gains and losses found no evidence for a curvilinear relationship between DD and age in a sample aged between 19 and 91 years (Löckenhoff, O'Donoghue, & Dunning, 2011).

High DoG has been shown to be a predictor of better cognition, motivation (to change), social competencies, health behavior, wellbeing, and life satisfaction (e.g., Forstmeier et al., 2011; Mischel et al., 2011; Mischel et al., 1989; Rosenbaum & Ben-Ari Smira, 1986; Shoda et al., 1990). In terms of clinical implications, Paper 1 drew attention to the importance of DoG for programs and interventions promoting primary, secondary, and tertiary prevention (see *Clinical Implications for Practice* for further recommendations).

Summary of Paper 2: SOEP Children's Study: Interactions of Cognition, Education, and Personality in Decisions between Immediate and Delayed Rewards in Mothers and their Children

The German Socio-Economic Panel (SOEP) children's study—a household study conducted in 2008—is a companion study to the well-known SOEP panel study (Siegel, Jänsch, & Stimmel, 2008). The original sample consisted of 291 mothers aged between 24 and 58 years and their 5- or 6-year-old children. While children's DoG was measured using the gummy bear experiment (see *Theoretical and Methodological Background*), the mothers answered a DD questionnaire based on hypothetical monetary rewards (Dohmen, Falk, Huffman, & Sunde, 2007).

Two papers analyzed the data from the SOEP children's study:

1. "Does the apple fall far from the tree? Intergenerational links and maternal antecedents in children's self-regulation from a household study" (Drobetz, Maercker, Spiess, Wagner, & Forstmeier, accepted)

2. “Interactions of cognition, education, and personality in decisions between immediate and delayed rewards in mothers and their children” (Drobetz, Maercker, et al., submitted). This is Paper 2 of the present thesis.

Before Paper 2 is summarized, the results of the paper “Does the apple fall far from the tree? Intergenerational links and maternal antecedents in children’s self-regulation from a household study” (Drobetz et al., accepted) are presented: As its title suggests, this paper explored intergenerational links in children’s self-regulation—that is, mother–child links of the same variable (i.e., self-regulation)—as well as maternal antecedents of self-regulation (e.g., maternal education). Previous studies have demonstrated a positive correlation between high parental self-control and high child self-control (Boutwell & Beaver, 2010). Further, high maternal intelligence has been linked to high child self-regulation (Colman et al., 2006).

The data analysis showed that both the child’s age and the maternal antecedent of duration of breastfeeding (in months) were significant predictors of children’s DoG, even when confounders such as maternal cognitive abilities and personality traits were controlled. Mediating mechanisms were found account for the link between the duration of breastfeeding and children’s DoG, namely children’s self-regulation of energy intake, neural processes, parenting styles, attachment security, bonding, and maternal variables such as sensitivity, intelligence, education, and personality traits. Contrary to the hypothesis of a positive correlation between mothers’ and children’s self-regulation, the data revealed a weak negative, but nonsignificant, correlation. One explanation may be that DoG and DD measure different facets of self-regulation. Further conclusions are presented in the *General Discussion* and in Drobetz et al. (accepted).

Paper 2 ("Interactions of cognition, education, and personality in decisions between immediate and delayed rewards in mothers and their children") took a different approach to address another research question, focusing on interactions of variables in predicting mothers' and children's self-regulation. Previous findings have shown that low DD is linked to high intelligence (e.g., Shamosh et al., 2008) and high education. High DoG has been associated with higher openness, conscientiousness, and agreeableness (Krueger, Caspi, Moffitt, White, & Stouthamer-Loeber, 1996). With respect to interactions of variables, undergraduate students with higher general cognitive ability and higher emotional stability have been found to have lower DD. Shamosh and Gray (2008) suggested that measures of both fluid and verbal intelligence be included in future DD studies. Against this background, another aim of Paper 2 was to examine whether the strength of association between DoG/DD and fluid and verbal intelligence differed.

Findings from the gummy bear experiment in Paper 2 showed that the older the child was (in months), the more likely he or she was to delay gratification. Prosocial behavior remained a significant predictor of children's DoG, even when potential confounders (e.g., children's age, cognitive abilities, or personality traits) were controlled. Children with higher verbal intelligence and higher prosocial behavior had higher DoG, as did children with higher verbal intelligence and higher agreeableness. Mothers with higher education and lower agreeableness had lower DD. Higher verbal intelligence was significantly correlated with higher DoG and lower DD in both children and mothers.

Both higher verbal intelligence and higher prosocial behavior are known to be linked to higher DoG (Long & Lerner, 1974; Mischel, 1961b; Mischel et al., 1988). Paper 2 further revealed an interaction between higher verbal intelligence and higher prosocial behavior in predicting children's DoG. With respect to the mothers, high education may compensate for low agreeableness. Note that the SOEP children's study focused on socially agreeable facets of the Big Five personality trait of agreeableness. Highly socially agreeable mothers may not necessarily delay hypothetical monetary rewards as DD is a special facet of self-regulation or impulsivity (Reynolds, 2006).

Summary of Paper 3: Structural Brain Differences between Elderly Individuals with Low versus High Delay of Gratification

This structural magnetic resonance imaging (sMRI) study used the recently validated DoG-A (Forstmeier et al., 2011), which requires delay decisions on the behavioral level. Specifically, this study sought to identify possible structural brain differences between individuals with low versus high DoG using sMRI, surface-based morphometry (SBM), and diffusion tension imaging. Paper 3 reports the results of the sMRI and SBM analyses. To the author's best knowledge, this was the first DoG study to use sMRI to examine the effects of primary and secondary rewards in a sample of elderly individuals. On the one hand, the dearth of sMRI studies may be due to the previous lack of adequate DoG measures for adults. On the other hand, it is relatively easy to present hypothetical monetary rewards to individuals lying in the scanner. Thus, DD was explored using sMRI, functional MRI (fMRI), and transcranial magnetic stimulation.

Previous imaging studies have consistently showed that DD, impulsivity, and related constructs such as risk taking are associated with the dorsolateral prefrontal cortex (DLPFC), the orbitofrontal cortex (OFC), the anterior cingulate cortex (ACC), and the striatum (Bjork, Momenan, & Hommer, 2009; Jäncke, Cheetham, & Baumgartner, 2009; Matsuo et al., 2009; McClure, Laibson, Loewenstein, & Cohen, 2004). In an sMRI study, lower DD was significantly related to higher inferolateral and DLPFC gray matter (GM) volumes (Bjork et al., 2009). Given previous findings on DoG-related constructs, Paper 3 predicted that, relative to non-delayers, delayers would have increased cortical thickness in prefrontal cortex regions. Further, Paper 3 predicted that delayers would have increased GM volumes in the striatum and nucleus accumbens. Additionally, because previous studies have reported higher DD for primary rewards (Forzano & Logue, 1992; Kirby & Guastello, 2001; Odum & Rainaud, 2003; Petry, 2001), larger clusters of cortical thickness differences were expected when DoG involved primary rewards than when it involved secondary rewards.

Paper 3 drew on a sample of 120 members of the cognitively unimpaired control group in the longitudinal MoReA study on motivational reserve as protective factor against mild cognitive impairment and mild Alzheimer's dementia. Two extreme groups were selected from this sample. Specifically, 20 delayers and 20 non-delayers aged between 63 and 93 years were chosen on the basis of their DoG-A total score (Forstmeier et al., 2011).

Compared with non-delayers, delayers had significantly increased cortical thickness in bilateral DLPFC regions and in the left ACC. Additionally, delayers had significantly larger GM volumes in the striatum. Conversely, non-delayers had increased cortical thickness in a cluster of the left orbitofrontal cortex (OFC), which proved to be larger in the context of primary rewards.

To conclude, DoG in the elderly is associated with structural changes in areas of the reward system as well as in cortical projection areas of dopaminergic neurons (e.g., the DLPFC). On the whole, the DLPFC is seen as a key area for the control of outcomes such as attention, working memory, presence (Jäncke et al., 2009), emotion regulation (Davidson, Putnam, & Larson, 2000) and risk-taking behavior (Jäncke, Brunner, & Esslen, 2008). Additionally, the DLPFC modulates the cortical network associated with behavioral psychological functions (Jäncke et al., 2008). Increased OFC thickness in non-delayers may reflect higher subjective value of immediate rewards (Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005; McKell Carter, Meyer, & Huettel, 2010). Whereas the left ACC is associated with response inhibition (Horn, Dolan, Elliott, Deakin, & Woodruff, 2003), the nucleus accumbens is associated with goal-directed behavior (Meredith, Baldo, Andrezjewski, & Kelley, 2008). Both response inhibition and goal-directed behavior are crucial for successful DoG (Freund & Baltes, 2002b; Reynolds et al., 2002).

GENERAL DISCUSSION

Delay of Gratification as a Domain-Specific, Multidimensional, and Stable Construct?

Domain-Specificity of Delay of Gratification

Paper 1 addressed the domain specificity of DoG. For example, an individual may have high DoG for money but low DoG for food, indicating domain specificity of or intraindividual differences in DoG. Whereas some authors have argued that DoG is learned and generalized across situations and rewards (Eisenberger & Adornetto, 1986; Karniol & Miller, 1983), others authors have contended that DoG is a domain-specific construct (Bembenutty & Karabenick, 1998; Ward, Perry, Woltz, & Doolin, 1989). Further, DoG is highly dependent on the situation: it is affected by individuals' experience of environmental contingencies (e.g., Metcalfe & Mischel, 1999), which may vary across domains.

DD tasks are generally seen as indicators of actual decisions. However, DD studies have found low correlations across domains. For instance, Chapman (1996) reported a low correlation (r = .11) between DD in the domains of money and health. Although studies comparing real and hypothetical monetary rewards have not found differences in DD (Johnson & Bickel, 2002; Lagorio & Madden, 2005; Madden, Begotka, Raiff, & Kastern, 2003), higher DD rates have been reported for primary rewards, such as food and alcohol (Forzano & Logue, 1992; Kirby & Guastello, 2001; Odum & Rainaud, 2003; Petry, 2001).

A factor analysis revealed that DoG could be divided into dimensions such as achievement orientation and career objectives (Ward et al., 1989). A recently published study with younger adults (students) and older adults (aged between 60 and

84 years) provided further evidence for domain specificity: DD of real liquid rewards did not significantly correlate with DD of hypothetical monetary rewards in either sample (Jimura et al., 2011). The Delaying Gratification Inventory (DGI) by Hoerger, Quirk, and Weed (2011), which is described in detail below (see *Behavioral versus Self-Report Measurement*) also considers the domain specificity of DoG. The DGI covers five DoG domains: 1. food, 2. physical pleasures, 3. social interactions, 4. money, and 5. achievement (Hoerger et al., 2011).

Paper 2 measured only one DoG domain in children (gummy bears; primary reward) and one DD domain in mothers (money; secondary reward). Thus, Paper 2 cannot contribute to research on the domain specificity of DoG. However, the results of Paper 3 showed that individual DoG can differ from domain to domain on both the behavioral and neural level. As described above, the primary reinforcer (snacks) led to significantly larger clusters in OFC regions. In conclusion, a global conceptualization of DoG can be rejected (e.g., Forstmeier et al., 2011; Jimura et al., 2011). Previous studies on the development and validation of the DoG-A have included four different rewards (snacks, real/hypothetical money, and magazines) to explore possible domain independence. A validation study showed that the different types of rewards were relatively independent. The snacks subscore proved to be the best indicator of DoG (Forstmeier et al., 2011).

Multidimensionality of Delay of Gratification

DoG is a multidimensional construct comprising aspects of self-regulation (Mischel, 1974), self-control (Metcalfe & Mischel, 1999), foresight (Eack, George, Prasad, & Keshavan, 2008), impulsivity (e.g., Monterosso & Ainslie, 1999), willpower (Mischel et al., 2011), and inhibition (Casey et al., 2011). The nomological network of

DoG is discussed in the *Theoretical and Methodological Background* section, and Paper 1 reviews the theoretical status of DoG.

Stability of Delay of Gratification

Do DoG behaviors remain interindividually stable or do they change over time? For instance, does a prior non-delayer of food become a delayer with increasing age? Is DoG in old age a state or a trait? One limitation of this thesis is that its findings cannot contribute to addressing this research question. However, the evidence suggests that individual differences in DD of liquid and monetary rewards remain stable over a 2- to 15-week interval (Jimura et al. (2011). Further, Odum's (2011) analysis of published DD data sets indicated that DD is actually a trait variable. Casey et al. (2011) also concluded that an individual's DoG remains relatively stable across the lifespan. Specifically, individuals whose preschool DoG as measured by the "marshmallow test" (Goleman, 1995; Mischel et al., 2011) was low also tended to show lower performance on a "go/no-go" task in adolescence, young adulthood, and their mid-40s (Casey et al., 2011; Eigsti et al., 2006).

Are Delay of Gratification and Delay Discounting Distinct Constructs?

Paper 1 discussed differences between DoG and DD on the behavioral level. MacKillop et al. (2011) characterized DD as a behavioral and economic indicator of impulsivity. According to Reynolds and Schiffbauer (2005), DoG and DD do not measure one and the same facet of impulsivity. Whereas some authors treat DoG and DD as identical concepts (e.g., Green, Fry, & Myerson, 1994; Johnson & Bickel, 2002; Schweitzer & Sulzer-Azaroff, 1995), there are strong arguments for differentiating between the two. Nevertheless, both constructs do refer to related processes (Reynolds & Schiffbauer, 2005).

A major difference between the DoG and DD paradigms is in the value of the rewards offered. Whereas money generally retains its value over time (disregarding inflation and economic crises), the value of primary rewards such as food decreases over time (Odum & Rainaud, 2003). As Mischel (1974) emphasized, both the value of the reward and the expectancy of success make a crucial contribution to DoG decisions. DD paradigms commonly use hypothetical monetary rewards (e.g., Kirby, Petry, & Bickel, 1999), assuming that money is of highest value for all individuals. What, however, if a respondent does not care about money? Recently, Forstmeier et al. (2011) showed that snacks have higher value for older individuals than do money or magazines (Forstmeier et al., 2011).

In Paper 2, 19 children whose mothers said that they did not like gummy bears much or at all were excluded from the analyses. The results might otherwise have been biased: Why should children for whom gummy bears do not have a high value delay or not delay eating them? As described above, DoG experiments need to offer real and attractive incentives in order to motivate participants (e.g., Wulfert et al., 2002). The 5- and 6-year-old children in the SOEP children's study (Paper 2) had to overcome the temptation of the open pack of gummy bears in front of them. In particular, the delaying children had to sustain their choice during the delay interval. In contrast, the mothers chose between an immediate €100 and a progressively increasing amount of money in each row or item. Whereas the gummy bears were real and attractive incentives for the children, the DD questionnaires remained hypothetical for the mothers. The DoG-A takes accounts of the value of rewards (snacks, magazines) for individual respondents, to the extent that participants have to state their preferences before the game.

Boutwell and Beaver (2010) found intergenerational links in self-control between parents and their children (i.e., links between the child's and the mother's/ father's score on the same variable). With respect to intergenerational links in self-regulation, data from the SOEP children's study revealed a negative correlation between DD in mothers and DoG in children (r = -.11). Although this correlation failed to reach significance (p = .07; (Drobetz et al., accepted), these findings may support the idea that DoG and DD are distinct concepts (Reynolds & Schiffbauer, 2005).

On the behavioral level, there were no significant correlations between the general DD rate (k) and the snacks subscore (r = -.10, p = .29) in the master sample (n = 118) of Paper 3. This result supports the distinction between DoG and DD (or primary versus secondary rewards), but is in contrast to the findings of the DoG-A validation study, which showed a weak but significant negative correlation between k and the snacks subscore (Forstmeier et al., 2011). These inconsistent findings may be explained by the respective measures of the Delay Discounting Test (e.g.; Forstmeier & Maercker, 2011; Kirby et al., 1999) and the DoG-A (Forstmeier et al., 2011) that are both dichotomous. Further research is needed to examine whether or not continuous (DoG) and dichotomous (DD) measures correlate significantly.

From the neural perspective, the same brain regions may be associated with both DoG and DD. As described in Paper 3, individuals with high DoG had significantly higher gray matter volumes in the DLPFC, consistent with findings for DD (e.g., Bjork et al., 2009). Thus, although DoG and DD differ on the behavioral level (Reynolds & Schiffbauer, 2005), DLPFC areas may be associated with both concepts on the neural level (see Paper 3).

Delay of Gratification Measurement

Behavioral versus Self-Report Measurement

On the one hand, DoG is traditionally measured by behavioral tests such as the "marshmallow test" (Goleman, 1995; Mischel et al., 2011) and the DoG-A (Forstmeier et al., 2011). On the other hand, self-report (or personality) measures of DoG (or related concepts such as impulsivity) exist. For an overview, please see Table 1 and self-report questionnaires such as the Delaying Gratification Inventory (Hoerger et al., 2011).

Both behavioral and self-report measures have their strengths and limitations: Behavioral measures are objective and not (or less) affected by social desirability or self-perception biases (Reynolds, Ortengren, Richards, & de Wit, 2006). Self-report questionnaires may be biased due to social desirability (Wulfert et al., 2002)—they depend on the insight, recall accuracy, and fair-mindedness of respondents—but they are easily administered (Dougherty, Mathias, Marsh, & Jagar, 2005). Further, they have a higher economic validity (they are cheaper and less time intensive) than, for example, the DoG-A, which entails higher financial costs and longer test times (Forstmeier et al., 2011).

Drawing a distinction between behavioral and self-report DoG/DD measures is important, as self-report questionnaires and behavioral measures of impulsivity seem to be unrelated (Reynolds et al., 2006). Indeed, there is growing evidence to suggest that the two approaches measure different aspects of impulsivity (e.g.; Morgan et al., 2011; Reynolds et al., 2006), which is a multidimensional construct (Dougherty et al., 2005). In contrast to impulsive disinhibition (as measured by, e.g., go/no-go tasks), the behavioral DD paradigm may cover only one facet of impulsivity, namely impulsive decision making. However, the generalizability of data collected from behavioral questionnaires to other behavioral contexts may be limited (Reynolds et al., 2006).

Hoerger, Quirk, and Weed (2011) recently developed and validated the Delaying Gratification Inventory (DGI). This novel DoG measure is a 35-item self-report questionnaire (5-point scale from 1 “strongly disagree” to 5 “strongly agree”) covering five DoG domains, namely food (e.g., *“If my favorite food were in front of me, I would have difficult time waiting to eat it”*), physical pleasures (e.g., *“I am able to control my physical desires”*), social interactions (e.g., *“I try to consider how my actions will affect other people in the long-term”*), money (e.g., *“It is hard for me to resist buying things I cannot afford”*), and achievement (e.g., *“I cannot motivate myself to accomplish long-term goals”*).

The advantage of the DGI and its 10-item short version and other self-report questionnaires is that they can be easily applied. However, they are far removed from Mischel’s original idea of a behavioral measure of self-regulation. Individuals may well present themselves as having a higher DoG than is in fact the case, as self-perceptions do not generally provide an adequate reflection of human behavior (Reynolds et al., 2006). In other words, self-reports may be highly sensitive to social desirability and self-perception biases, because the goal of questionnaire measures is more directly transparent (Reynolds et al., 2006; Wulfert et al., 2002).

How might the gap between behavioral and self-report measures of DoG be bridged? Reynolds et al. (2006) offered two suggestions: Either behavioral measures should aim at assessing more dimensions of impulsive behavior, or self-report measures should relate to more specific processes, of the kind covered in behavioral measures.

Dichotomous versus Continuous Measurement

Silverman (2003) describes two traditional approaches to assessing DoG, namely dichotomous and continuous measures (see Paper 1). In dichotomous measures, respondents have to make fixed choices between immediate smaller and delayed larger rewards on each trial (i.e., commitment choices). In continuous procedures, in contrast, respondents have to sustain their choice (e.g., by resisting the marshmallow in front of them; (Silverman, 2003).

The DoG-A developed by Forstmeier, et al. (2011) (see Papers 1 and 3) can be seen as a dichotomous measure of DoG as it involves commitment choices: Respondents have to make a fixed choice on each item. The SOEP children's study used both approaches: a continuous measure for children and a dichotomous measure for mothers (Paper 2). Specifically, the children willing to wait for the second pack of gummy bears had to sustain their choice until the interview with the mother was complete. The mothers had to choose between a fixed €100 now and a successively increasing amount of money in 6 months (between €101.20 and €124.80).

It is only recently that DoG (of primary rewards) has been studied in samples of adults (Knolle-Veentjer, Huth, Ferstl, Aldenhoff, & Hinze-Selch, 2008) and older individuals (Forstmeier et al., 2011; Jimura et al., 2011). One reason for the previous lack of DoG studies in these age groups may be that continuous DoG procedures, in particular, are suitable only for children. In other words, Michel's original DoG paradigm ("marshmallow test"; Goleman, 1995; Mischel et al., 2011) may be difficult or impossible to adapt for use in studies with adolescents, adults, and the elderly. In continuous measures, delay intervals suitable for children's experience and perception of time span only a few minutes. In contrast, studies in adults require both meaningful delay intervals (days or weeks) and rewards. Whereas marshmallows allow reliable measurement of DoG in children, the challenge of finding adequate, age-appropriate incentives may be another reason for the lack of DoG studies in older adults.

Nevertheless, it may be questioned why the DoG-A does not require sustained choices (e.g., for chocolate). First, it seems doubtful that 20 minutes are a meaningful delay interval for adults (Forstmeier et al., 2011). However, in an experiment using liquid rewards, participants choosing the delayed gratification had to wait a maximum of 60 seconds (Jimura et al., 2011). Second, with increasing delay interval, confounding influences may bias the sustained choice (e.g., foreseeable hunger, distraction). Third, when the delay interval is filled with a task—e.g., answering questions while sustaining the choice—a goal conflict may occur: Individuals may want both to sustain their decision to resist the tempting reinforcer in front of them and to perform well in the questions. Further, other tasks make it easier to focus on stimuli other than the desired and tempting one; this phenomenon is termed cognitive distraction or allocation of attention (Cournoyer & Trudel, 1991; Mischel, 1974; Owen, Martin, Whincup, Smith, & Cook, 2005; Vaughn, Krakow, Kopp, & Johnson, 1986; Yates, 1987).

Primary versus Secondary Rewards

On the whole, the value of the reward and the expectancy of success are the primary influences on DoG decisions (Mischel, 1974). Food is more sensitive to failures of self-control: Previous studies have reported higher DD for primary reinforcers that can be consumed directly (food, drinks) than for secondary reinforcers (money) (Forzano & Logue, 1992; Kirby & Guastello, 2001; Odum & Rainaud, 2003; Petry, 2001). Jimura et al. (2011) showed that that there was no significant correlation between DD rates for real primary rewards (liquids) and hypothetical secondary rewards (hypothetical money). Thus, the authors suggested that DD of primary and secondary rewards may involve separate aspects of impulsivity. This may also explain the low but nonsignificant (intergenerational) correlation between children's DoG as measured with gummy bears and maternal DD as measured with hypothetical money (Drobetz et al., accepted) and the nonsignificant correlation between children's and mothers' self-regulation.

The data obtained from the master sample (n = 118) of Paper 3 provided further evidence for the distinction between primary and secondary rewards. There were no significant correlations between the snacks subscore and the hypothetical money subscore (r = .11, p = .22), the snacks subscore and the real money subscore (r = .08, p = .41), or the snacks subscore and the magazines subscore (r = .08, p = .38). In contrast, the hypothetical and the real money subscore did correlate significantly (r = .42, p < .001), as did the secondary rewards of money and magazines: Individuals with high magazines subscores showed both high hypothetical money subscores (r = .29, p < .01) and high real money subscores (r = .26, p < .01). The imaging results (see Paper 3) suggest that snacks have higher value for older individuals than money or magazines, consistent with the findings of the DoG-A validation study (Forstmeier et al., 2011).

Delay of Gratification and Verbal Intelligence

Freud (1911/1959) argued that children are first driven by the id, but learn with time to transform their cravings into so-called internal images that help them to direct their efforts. In children, successful DoG has been linked to cognitive reappraisal or distraction—that is, to the verbally driven reinterpretation of the meaning of a significant stimulus (Gross, 2001; Ochsner, Bunge, Gross, & Gabrieli, 2002). A longitudinal study found evidence for a positive association between verbal capacities and DoG: The longer preschoolers could wait for a delayed reward, the higher their verbal fluency in adolescence (Mischel et al., 1988). Verbal capacities may make cognitive distraction easier by improving the (verbal) focus on other stimuli (e.g., Mischel, 1974). Additionally, verbal intelligence is defined as "the extent to which a person has absorbed the content of culture" (Belsky, 1990, p. 125). In fact, socialization and cultural processes are also seen as explanations for individual differences in DoG (Wulfert et al., 2002).

Paper 2 used the Peabody Picture Vocabulary Test (Dunn & Dunn, 1997; Rossbach, Tietze, & Weinert, 2005) to measure children's verbal intelligence, and the Multiple Choice Vocabulary Test (Lehrl, Triebig, & Fischer, 1995) to assess mothers' crystallized intelligence. Paper 3 used the German Wortschatztest (WST, Schmidt & Metzler, 1992) to measure verbal intelligence, which is known to remain relatively preserved in old age (Lehrl et al., 1995). Both children's and mothers' verbal and crystallized intelligence correlated significantly with DoG/DD (Paper 2), but there were no significant differences in verbal intelligence between delayers and non-delayers in the sample of elderly adults (see Table 7). Likewise, there were no significant differences in the WST of delayers and non-delayers in the master sample (control group) of $n = 118$, $t(116) = 1.73$, $p = .09$ (two-tailed). Nonetheless, DD and verbal intelligence showed a significant negative correlation ($r = -.20$, $p < .05$). Further, the higher an individual's verbal intelligence, the lower their DoG for magazines ($r = -.19$, $p < .05$). It seems reasonable to speculate that individuals with higher verbal intelligence are more interested and reading and thus perhaps more likely to opt to receive a magazine immediately.

Papers 2 and 3 thus yielded contradictory results with respect to the relationship between DoG and verbal intelligence. However, the studies assessed different age groups: 5- and 6-year-old children, women between 24 and 58 years (Paper 2), and older adults between 63 and 93 years (Paper 3). There is at least one potential explanation for the differences found: With increasing age, factors other than verbal intelligence—e.g., mental health or affective response (Löckenhoff et al., 2011)—may account for interindividual differences in DoG. For instance, older adults may use strategies other than verbal strategies to sustain the choice of a delayed reward (see *Implications for Research*).

Neural Substrates of Delay of Gratification

Paper 3 provides an extensive discussion of the neural substrates of DoG, DD, and impulsivity as well as activation patterns investigated with fMRI.

A recently published fMRI study showed that the frontostriatal circuity (right inferior frontal gyrus) seems to be associated with high DoG (resisting temptation). Whereas low delayers had lesser recruitment of the inferior frontal gyrus, the ventral striatum demonstrated higher activation in low delayers during resisting processes (Casey et al., 2011). Optimal decisions in financial risk choices involve mesolimbic circuits correlated with expected value information (Samanez-Larkin, Wagner, & Knutson, 2011). Overall, the findings of Paper 3 are in line with those of Casey et al. (2011) and Samanez-Larkin et al. (2011).

The DLPFC has been associated with executive function, and particularly with working memory (e.g., MacPherson, Phillips, & Della Sala, 2002; Rowe, Toni, Josephs, Frackowiak, & Passingham, 2000), which are in turn linked with DoG and DD (e.g.; Bickel, Yi, Landes, Hill, & Baxter, 2011; Carlson, 2005; Hinson, Jameson, & Whitney, 2003). It is a key brain region for the control of behavioral aspects, such as top-down and bottom-up control of attention, motor behavior, egocentric orientation, working memory, presence (Jäncke et al., 2009), risk-taking behavior (Jäncke et al., 2008), and emotion regulation (Davidson et al., 2000). It is also a modulator of the cortical network associated with behavioral psychological functions (Jäncke et al., 2009).

Delay of Gratification across the Lifespan

This thesis has contributed to research on DoG across the lifespan in several ways. First, it analyzed samples from different stages in the lifespan: children (Paper 2), women (Paper 2), and older individuals (Paper 3). Second, Paper 1 summarized the results of DoG research across the lifespan (see Table 2). Third, the *General Discussion* brought together Papers 1, 2, and 3 from the perspective of lifespan psychology. Paper 3 contributed to the evidence that DoG remains crucial in old age (Forstmeier et al., 2011).

Goals play a vital role in the life course, impacting individual wellbeing and life satisfaction (Brunstein, Schultheiss, & Grässman, 1998; Brunstein, Schultheiss, & Maier, 1999). The association between high DoG/low DD and high life satisfaction may also hold across the lifespan. High life satisfaction was a significant predictor of low DD in females aged between 24 and 58 years (Paper 2). The DoG-A validation study showed that wellbeing was a significant predictor of DoG in individuals aged between 60 and 94 years (Forstmeier et al., 2011). Finally, in the master sample in Paper 3 (n = 118), individuals with high DoG for snacks had significantly higher scores in the SF-12 Health Survey (Bullinger & Kirchberger, 1998) subscale of mental health ($r = .23$, $p < .05$).

IMPLICATIONS

Outlook

The author of this thesis is currently working on a paper exploring the role of cognitive impairment and age-related effects on DoG and DD. As described in Paper 1 and in the *Nomological Network of Delay of Gratification* section, DoG has been linked to executive functions (e.g., Carlson, 2005). Given previous findings of a decline in executive function with increasing age and cognitive impairment, it was predicted in the context of the MoReA study that individuals with mild cognitive impairment and early Alzheimer’s disease would have lower DoG than would cognitively unimpaired controls. Further, the study predicted a decrease in DoG with increasing age as well as a negative correlation between DoG, on the one hand, and cognitive status and subjective life-expectancy variables as well as time perspective, on the other.

The data obtained in the context of the sMRI study (Paper 3) make it possible to analyze white matter integrity using diffusion tension imaging (fractional anisotropy).

Implications for Research

To the author’s best knowledge, longitudinal studies of DoG including elderly respondents are currently lacking. However, only longitudinal analyses would make it possible to examine stability or change of DoG across the lifespan. The evidence suggests that DoG and DD are relatively stable traits (Casey et al., 2011; Jimura et al., 2011; Odum, 2011). In particular, the findings of Casey et al. (2011) are impressive: These authors showed that individuals’ resistance to temptation remained stable over a

40-year span. However, further research is needed to examine whether DoG remains stable in old age. Future studies need to obtain repeated measures of DoG in older adults in order to determine whether DoG changes with increasing age, and which factors contribute most to any changes observed. The ongoing MoReA study will allow such longitudinal data analyses, as the DoG of cognitively impaired respondents is being measured at four points of testing.

In general, the evidence suggests a curvilinear relationship between DD (secondary reinforcers) and age (Harrison, Lau, & Williams, 2002; Read & Read, 2004; Sozou & Seymour, 2003; Trostel & Taylor, 2001). However, a recently published study using hypothetical secondary rewards was unable to confirm this relationship in a lifespan sample (Löckenhoff et al., 2011). Further research might investigate whether there is a curvilinear relationship for primary rewards and elucidate the mixed results reported for secondary rewards (Harrison et al., 2002; Löckenhoff et al., 2011; Read & Read, 2004). Additionally, future studies could compare the behavioral DoG-A measure (Forstmeier et al., 2011) with the newly introduced DGI self-report measure (Hoerger et al., 2011).

Furthermore, it would be interesting to investigate the processes underlying DoG decisions in adulthood and in old age. How do adults and the elderly resist and overcome the temptation of immediate rewards? Does cognitive distraction help them to delay rewards? Which other variables or processes play a crucial role (e.g., goals, willingness, oversaturation, pleasant anticipation of a delayed gratification)? It may be worth exploring whether adult non-delayers are simply unwilling to wait (voluntary non-delayers) or are unable to wait for the delayed reward (unintended non-delayers, e.g., due to low self-regulation/high impulsivity). Future studies should also consider individual mood and affect; negative mood has been linked to higher DD/lower DoG and positive affect to lower DD/higher DoG in children and adults (Koff & Lucas, 2011; Moore, Clyburn, & Underwood, 1976; Pyone & Isen, 2011).

Whereas the SOEP itself is a longitudinal panel study that was initiated more than 25 years ago, the SOEP children's study has a cross-sectional design (data were assessed in 2008) that could potentially be extended into a longitudinal exploration of former delayers and non-delayers (Paper 2). Researchers could address a wide range of clinical and developmental research questions in this context. Specifically, extensions of the SOEP children's study could investigate how DoG in childhood relates to later cognitive status, onset of dementia in old age, and health status and the development of mental health disorders across the lifespan. Analysis of the relationship between childhood DoG and later life outcomes could potentially provide further confirmation of the benefits of high DoG.

The SOEP children's study used packs of gummy bears to measure DoG in children and hypothetical monetary rewards to measure DD in mothers (Dohmen et al., 2007). With respect to intergenerational comparisons, children's DoG and maternal DD were negatively correlated, but the correlation failed to reach significance. Future studies exploring intergenerational links in the self-regulation of parents and children should consider using comparable procedures to measure facets of self-regulation. As the gummy bear experiment has proven to be an adequate measure of DoG in children, future studies could also use snacks to experimentally assess DoG in parents (e.g., with the DoG-A). This approach would allow an intergenerational comparison between children and their parents on the basis of corresponding measures. In addition, it would be worth exploring the reciprocal influences of parents and children on DoG.

The results of Paper 3 also raised further research questions. First, future sMRI studies could directly test for possible structural brain differences between DoG and DD when the two constructs are assessed separately. The necessary design would involve four subgroups: Individuals with high and low DoG and individuals with high and low DD, with DoG being measured in the DoG group only and DD being measured in the DD group only. In addition, future sMRI studies should include younger lifespan samples and, for example, compare children, adolescents, younger, middle-aged, and older adults. Second, fMRI studies could use a modified version of the DoG-A to explore activation patterns of immediate versus delayed choices. Third, sMRI studies could explore the impact of specific DoG interventions. For instance, sMRI could determine whether the cortical thickness of the DLPFC, the ACC, and the striatum increases in non-delayers after DoG enhancement.

The DoG-A snacks subscale proved to show the most consistent and most significant patterns on both the behavioral and neural level (please see Paper 3 and Forstmeier et al., 2011). Thus, future research might consider using only the DoG-A snacks subscale to measure DoG and the Delay Discounting Questionnaire (Forstmeier & Maercker, 2011; Kirby et al., 1999) to measure DD. Dropping the real money and magazines subscales would also lower the costs of the DoG-A and thus increase its economic validity. However, the full version of the DoG-A could be used in adolescents, young and middle-aged adults in order to compare DoG across age groups.

Clinical Implications for Practice

Recent findings have confirmed that the ability to delay gratification predicts numerous positive outcomes. There is an urgent need for the transfer and application of this research knowledge into practice (e.g., in treatment programs).

A recent meta-analysis confirmed the strong link between addictive behavior (with respect to, e.g., nicotine, alcohol, opiates, amphetamines, gambling) and high DD (MacKillop et al., 2011). Further, individuals with bipolar disorder and schizophrenia have been shown to have higher DD than healthy controls (Ahn et al., 2011). Overweight and obese women with high DD and higher food reward sensitivity showed greater palatable food intake (Appelhans et al., 2011). In the elderly, DD of monetary rewards differentiated between high- and low-lethality suicide attempts: High-lethality suicide attempters had lower DD than did low-lethality attempters. Better planned suicidal acts were also correlated with low DD. Thus, highly impulsive individuals (higher DD) seem to tend to less serious and poorly planned suicide attempts (Dombrovski et al., 2011).

The results of Papers 2 and 3 support the implementation of DoG interventions. Specifically, future studies could develop and evaluate specific training programs for the prevention and treatment of deficits in DoG (e.g., substance dependence, pathological gambling, impulse shopping, financial problems). DoG may also be essential for maintaining health behavior—a fact that may be useful for programs promoting health-related behavior. Moreover, DoG is not only important for primary prevention—the success of secondary and tertiary prevention also depends on self-regulated behavior (e.g., people with diabetes mellitus need to avoid glucose).

Cognitive behavioral psychotherapy and intervention programs for individuals with mental health disorders usually define treatment goals; however, psychotherapists are frequently confronted with difficulties such as lack of patient motivation, loss of interest, etc. (Forstmeier & Rueddel, 2007). Patients' volition (e.g., self-motivation, impulse control, emotion regulation) plays an important role in successful treatment (e.g., Beckmann & Kellmann, 2004) and can be trained in special programs (Forstmeier & Rueddel, 2007). In a nutshell, the present research has clinical implications for practice in two respects: First, interventions can aim to enhance DoG in individuals with low DoG. Second, they may instead train compensation strategies, such as detailed planning and external timers.

With respect to mental health, which strategies can be used to enhance DoG in adults—either to prevent mental disorders or to foster change processes in psychotherapy? Inasmuch as self-control and motivational self-regulation are necessary preconditions for the implementation and maintenance of treatment goals, every successful psychotherapeutic treatment may include strategies to foster DoG in the patient. Strategies that can be applied across disorders include the following Forstmeier (2005):

1. Bringing to mind the positive consequences of reaching the goal:

   The positive consequences of a long-term goal correspond to the delayed rewards in the DoG paradigm. Patients list all potential positive effects on a piece of paper (Karoly & Kanfer, 1982). They then remind themselves of these consequences as often as possible and visualize themselves experiencing them. This will motivate them to persevere and eventually reach the delayed goal.

2. Elaborating on the personal meaning of reaching the goal:

   DoG is much easier when the goal is supported by other elements of the self system (e.g., the individual's values, motives, and needs). A motivation analysis may reveal that the current goal is supported by some of these deeply rooted motivational aspects (e.g., Emmons, 1986). Reminding oneself of the deeper meaning and value of delaying the reward may be not easy, but very effective in increasing DoG.

3. Breaking down larger goals into substeps:

   Delaying gratification is easier when attention is focused on smaller steps rather than on the larger goal (Bandura & Schunk, 1981). Subdividing a long-term goal into substeps, or slowly increasing the level of difficulty, is therefore a simple but important strategy for enhancing DoG.

4. Self-rewarding for reaching substeps:

   Once the patient has identified weekly or daily substeps that will eventually lead to the desired goal, he or she can choose and adopt self-reward strategies (Lewinsohn, 1974). These include pleasant activities such as walking, eating a snack, or watching TV after completing a substep. Another category of self-reward is positive self-instruction (e.g., "Well done!").

5. Bringing to mind the progress made and previous successes:

   The ability to persevere and delay gratification increases when patients monitor the progress they have made toward the larger goal, and review this progress and previous successes on a regular basis (Karoly & Kanfer, 1982). In addition, individual resources can be activated to facilitate attainment of the goal.

6. Reassuring oneself:

   Encouraging self-instructions such as "I'll make it!" and "I'm able to do that!" are important in delaying gratification (Beck, Rush, Shaw, & Emery, 1987). Patients learn to monitor their motivational state and to strategically employ appropriate self-talks.

7. Arousing interest in the task:

   The actions needed to approach the goal often are difficult, aversive, or boring, which is a reason for not delaying gratification. Patients who succeed in arousing interest in those actions will strengthen their ability to delay gratification. Examples of strategies for arousing interest are making a game of the task, focusing on easier and perhaps amusing elements of the action, or introducing variety to the sequence of action (Green-Demers, Pelletier, Stewart, & Gushue, 1998).

As described in the *Importance of Delay of Gratification* section and at the beginning of this chapter, low DoG has been associated with various problematic behaviors and mental health disorders including violence, substance abuse and addiction, obesity, and antisocial personality disorder (Baumeister & Heatherton, 1996; MacKillop et al., 2011; Petry, 2002; Seeyave et al., 2009) that impact individual, societal, and economic functioning (Casey et al., 2011). Therefore, low DoG has tremendous societal costs (e.g., treatment costs for individuals with substance abuse or obesity). There is thus a clear need for interventions to enhance DoG. Previous research has found evidence for the intraindividual stability of DoG/DD across the lifespan (Casey et al., 2011; Odum, 2011). These findings raise the following questions: Is DoG nevertheless modifiable? Can a non- or low delayer become a high delayer? A recent study has demonstrated possible changes in DD behavior: Working memory training decreased delay discounting among stimulant addicts (Bickel et al., 2011). This finding indicates that the ability to delay gratification is not fixed and unchangeable. Rather, DoG is modifiable and changeable.

Paper 1: Delay of Gratification in Old Age: Assessment, Age-Related Effects, and Clinical Implications

(Drobetz, Maercker, & Forstmeier, 2012)

Abstract

Delay of gratification (DoG), the ability to reject immediately available smaller rewards in favor of later larger rewards, has been a topic of continuous research interest for almost 60 years. Although numerous studies have explored this construct and its effects on wellbeing, social behavior, cognitive abilities, and academic success in children, DoG studies in adulthood and old age are scarce. Instead, delay discounting (DD), that is, the degree to which individuals devalue delayed rewards, has been used in samples of adults and older individuals, and is of particular interest in clinical studies. Findings from DD research suggest that the preference for delayed rewards increases from childhood to early adulthood, and then decreases from middle age to old age.

The main aim of this review is to elucidate the importance of DoG in adulthood and old age. First, the review explores the theoretical status of DoG by specifying the relationships and distinctions between DoG and related constructs. Second, it provides an overview of DoG measurements, from traditional to novel. Third, the effects of DoG on development and wellbeing are explored. Fourth, age-related differences in DoG are summarized. Lastly, the review closes with conclusions, clinical implications, and the outlook for possible further research directions.

Keywords: age-related differences, assessment of delay of gratification, delay discounting, delay of gratification, self-regulation

Introduction

If you had the choice between one marshmallow now or two marshmallows later, which would you prefer? This question from Walter Mischel's (1974) original "marshmallow test" represents a dilemma which confronts us almost every day of our lives: the choice between an immediate reward and a larger delayed reward which implies the investment of time and effort. In scientific language, this behavior is termed *Delay of Gratification* (DoG)—the voluntary postponement of immediate gratification for the sake of later and better rewards (Mischel et al., 1989).

DoG has been a topic of psychological research interest for almost 60 years. The DoG paradigm was inspired by the work of psychologist Walter Mischel, who is well-known for his pioneering DoG experiments. The concept was originally investigated in children, and there is only a small body of research on DoG in adulthood and old age. However, it is not only children and adolescents who choose to delay or not to delay gratification; adults and elderly people also have to make daily choices between immediate and delayed pleasures. For example, they may have to decide between spending their money (e.g., a life insurance payout) now, or saving it for their heirs. Likewise, diabetes patients may decide against delicious sweets in view of the expected health payoffs. From a lifespan perspective, practical examples are plentiful: stopping smoking to reduce health risks, or working for the gratification of a pension in old age. Thus, DoG is also highly relevant in old age.

In this review, we first describe the theoretical basis of DoG and its link to related constructs. We then provide an overview of traditional and novel assessment procedures and empirical findings with regard to the effects of DoG on cognition, motivation, social variables and wellbeing, and summarize age-related differences in

DoG. The review closes with conclusions, clinical implications, and the outlook for possible further research directions.

Theoretical Status of Delay of Gratification

Much theoretical work has been done to explain DoG behavior and to localize DoG in the nomological network of the related constructs of self-regulation, delay discounting, and executive function.

Self-regulation

Self-regulation, a complex multifaceted personality process, involves internal and/or transactional processes that enable goal-directed activities to be maintained (Baumeister & Heatherton, 1996). Both self-regulation and DoG involve the active management of goals (Freund & Baltes, 2002a). Some authors see DoG as a measure of self-regulation (e.g. Mazur, 1987); indeed, the DoG paradigm has been used in studies on the development of self-regulation (Demetriou, 2000). Likewise, Academic DoG, i.e., delaying gratification in order to attain academic success, and self-regulated learning strategies are closely related (Bembenutty & Karabenick, 2004), and theories of self-regulation also draw on DoG (Baumeister & Heatherton, 1996). Successful self-regulation is necessarily accompanied by successful DoG—for example, when individuals prevent themselves from thinking about immediately available rewards (Mischel, 1974). Conversely, failure of self-regulation (i.e., choosing the immediate reward) tends to be accompanied by an attentional shift to that reward (Karniol & Miller, 1983).

Delay Discounting

Humans discount the value of delayed gratification. Given the choice between two equal rewards, one immediate and one delayed, they usually take the immediate one. A delayed reward is chosen only if it is larger than the immediate one (Green, Myerson, & Ostaszewski, 1999). DD is the degree to which an individual devalues delayed rewards (Ainslie, 1975; Rachlin & Green, 1972). In other words, as the delay increases, the value of the reward and hence the likelihood of its sustained choice decreases. The hyperbolic function most accurately describes DD curves for delayed reinforcers (Reynolds et al., 2002).

Although DoG and delay discounting (DD) are often seen as related or even identical, the empirical evidence also suggests differences between the two (Mischel et al., 1988; Reynolds & Schiffbauer, 2005). Whereas DoG calls for sustained choices, DD involves commitment choices. The "sustained choice" procedure used in traditional DoG experiments requires individuals to sustain their choice of the delayed reward during the delay period, overcoming the temptation to defect to the immediate, smaller, and continually available reward. DD procedures, in contrast, confront participants with unchangeable and separate choices for either the immediately available or the postponed stimulus on each trial (Green et al., 1994; Reynolds & Schiffbauer, 2005).

Executive functions

The term "executive function(ing)" covers various functions and skills that "enable a person to engage successfully in purposeful, self-serving behaviors" (Lezak, 1995, p. 42). Executive functions include, for example, attentional flexibility (Hongwanishkul et al., 2005) or inhibition (of predominant responses) (Salthouse, Atkinson, & Berish, 2003). Executive subfunctions cooperate in goal-directed problem-solving (Hongwanishkul et al., 2005) and provide the basis for making decisions, maintaining action, and regulating the self (Baumeister, 1998).

Zelazo and Müller (2002) distinguished between hot and cold executive functions. Cold executive functions are primarily cognitively operated and emotionally neutral (e.g., working memory, planning), whereas hot executive functions are affectively loaded (e.g., delay of rewards, regulation of motivation and emotion, stimulus control) (Metcalfe & Mischel, 1999; Zelazo, Qu, & Müller, 2005). From this theoretical perspective, DoG involves hot executive functions—including the anticipation of future consequences and perseverance.

There is scientific consensus that the frontal lobes, especially the prefrontal cortex, are the neural substrates of executive functions (Salthouse et al., 2003; Stuss & Benson, 1986). More specifically, the ventromedial prefrontal cortex is seen as the brain area involved in hot executive functions, and the dorsolateral prefrontal cortex in cold ones.

Assessment of Delay of Gratification—from the Traditional to the Novel

Traditional Behavioral Assessment of Delay of Gratification in Childhood

There are basically two traditional procedures of DoG assessment (see Silverman, 2003). First, Walter Mischel developed the *continuous measure* of DoG for studies with young children (usually between the ages of 4 and 6 years). In this procedure, the experimenter leaves the participants alone in a room with a bell and one marshmallow in front of them. The experimenter informs the children that they will get a smaller reward (usually one marshmallow or one cookie) if they call the experimenter by ringing the bell. However, if they wait until the experimenter returns (after about 20 minutes; participants were not told how long they would have to wait), they will get a larger reward (two marshmallows). The number of seconds of waiting is recorded and used as a continuous variable (Mischel, 1974).

Second, the *dichotomous measure* of DoG involves a single question. The experimenter asks participants whether they would prefer a small reward now, or a larger reward later (e.g., in one hour). This procedure yields a dichotomous variable, as participants can only make one choice between two options (Silverman, 2003).

Self-report Questionnaires for Adults

It has been proposed that DoG measures used with adults require not only meaningful delay intervals (days and weeks instead of minutes), but also meaningful and attractive rewards (Wulfert et al., 2002). However, it is difficult to find viable and non-trivial rewards for adults. Consequently, many researchers have used questionnaires to assess DoG in adults. Table 1 provides an overview of the self-report questionnaires available for the broad field of DoG.

The advantage of these self-report measures is clearly that studies can easily apply them to samples of adults and older people. However, all the approaches to assessing DoG in adulthood described go far depart from the original idea of a *behavioral* measure of self-control. A further problem of assessing DoG by self-report questionnaires is that responses may be affected by social desirability bias. In other words, respondents may present themselves as having higher ability to delay gratification than is actually the case.

Table 1 Self-report Questionnaires Assessing Delay of Gratification

Name	Focus of measurement	No. of items	Scale / response format	Example items
Deferment of Gratification Questionnaire (DGQ) (Ray & Najman, 1986)	Deferment of gratification	12	Yes/no; Witt (1990) version with 5-point Likert scale from "1 = definitely disagree" to "5 = definitely agree"	*Are you good at saving your money rather than spending it straight away?* *Do you agree with the philosophy: "Eat, drink and be merry, for tomorrow we may be all dead"?*
Multidimensional Delay of Gratification Scale (MDG) (Ward et al., 1989)	Delay of gratification with 5 dimensions: 1. Personal consumer 2. Academic concerns 3. Career concerns 4. Individual sociopolitical issues 5. Group sociopolitical issues	30	Forced-choice	Personal consumer: (a) *I would rather spend the money I make to buy fashionable clothes now, or* (b) *save the money I make to buy a car in two years* Academic concerns: (a) *I would rather stay in school and travel after graduation, or* (b) *take a year off and travel, even if it means falling behind in school*
Academic Delay of Gratification Scale (ADOGS) Adaptation of MDG (Bembenutty & Karabenick, 1998)	Situationally specific academic delay of gratification in a given course	10	Forced-choice; additional rating of strength of choice ("definitely" or "probably")	Paired non-academic and academic alternatives; *Go to a party the night before a test* OR *Study first and party only if you have time*
Monetary Choice Questionnaire (MCQ) or Kirby Delay Discounting Questionnaire (KDDQ) (Kirby et al., 1999)	Delay discounting, interpreted as impulsivity or self-control	27	Forced-choice (1 of 2 alternatives)	Decisions between two hypothetical amounts of money which differ in size and delay: smaller sum now versus larger sum at a later time: *Would you prefer $34 today, or $50 in 30 days?*
Short Self-Regulation Questionnaire (SSRQ) (Neal & Carey, 2005)	Overall self-regulation: 1. Impulse control factor 2. Goal setting factor	31	5-point scale from "strongly disagree" to "strongly agree"	*I am able to resist temptation.* *It's hard for me to notice when I've "had enough" (alcohol, food, sweets).*
Brief Self-Control Scale (BSCS) (Tagney, Baumeister, & Boone, 2004)	Self-control	13	5-point scale from "not at all" to "very much"	*I am good at resisting temptation.* *I spend too much money.*
Barratt Impulsiveness Scale (BIS) (Patton, Stanford, & Barratt, 1995)	Impulsiveness	30	4-point scale from "rarely / never" to "almost always / always"	*I save regularly.* *I spend or charge more than I earn.*
Future Orientation Scale (Steinberg et al., 2009)	1. Time perspective 2. Anticipation of future consequences 3. Planning ahead	15	Choice of best descriptor (forced-choice) and rating of descriptor ("Really true for me" or "Sort of true for me")	Anticipation of future consequences: *Some people would rather save their money for a rainy day than spend it right away on something fun* BUT *Other people would rather spend their money right away on something fun than save it for a rainy day*
Zimbardo Time Perspective Inventory (ZTPI) (Zimbardo & Boyd, 1999)	1. Past-negative time perspective 2. Past-positive time perspective 3. Present-fatalistic time perspective 4. Present-hedonistic time-perspective 5. Future time perspective	56	5-point scale from "very untrue" to "very true"	Present-hedonistic – present-orientation (= immediate DoG): *Spending what I earn on pleasures today is better than saving for tomorrow's security* Future orientation (= delayed DoG): *Before making a decision, I weigh the costs against the benefits*

Single Behavioral Measures of Delay of Gratification for Adolescents and Adults

A study of individuals with schizophrenia and controls used a board game for DoG measurement. At designated fields on the board, participants had to decide between two immediate snacks (chocolate drops, gummy bears, or crisps) or continuing to play and receiving double that amount (four delayed snacks) at the end of the game. The authors implemented a large number of trials (70 times two vs. four snacks) and observed a decrease in impulsive choices over the choice of the game (Knolle-Veentjer et al., 2008).

In sum, most studies on DoG and DD have applied monetary rewards. Some authors used hypothetical money (e.g., Madden et al., 1997) others real monetary incentives (e.g., Wulfert et al., 2002). Wulfert et al. (2002) highlighted two aspects requiring consideration in experimental DoG studies. First, the incentives offered must be attractive enough to motivate participants. For instance, money is an almost universal incentive. Second, it is important to bear in mind that the amount of a reward and its delay interact dependently (Chapman, 1996; Green & Snyderman, 1980; Kirby, 1997). For example, most people would choose \$200 in 20 weeks over \$190 in 19 weeks, but \$190 immediately rather than \$200 in a week's time (Herrnstein, 1990). Thus, in DoG studies, choices between two incentives should include a preference equilibrium at the beginning. In particular, monetary choice tasks should involve varying amounts of money and delay intervals (Wulfert et al., 2002).

Comprehensive Behavioral Measure of Delay of Gratification in Adulthood

The Delay of Gratification Test for Adults (DoG-A) is a more comprehensive behavioral measure of motivational self-regulation which can be applied with adults and older people (Forstmeier et al., 2011). It consists of four decision tasks involving four different types of rewards—snacks, hypothetical money, real money, and magazines (partly adapted from Knolle-Veentjer et al., 2008; Wulfert et al., 2002). We refer interested readers to Forstmeier et al. (2011) for a comprehensive description of the DoG-A and evaluation and validation results.

Effects of Delay of Gratification

Numerous studies have investigated the effects of DoG on wellbeing, social behavior, cognitive abilities, and academic success. Although most studies to date have focused on the effects of DoG in children and adolescents, there have been some studies with samples of adults and older people. Table 2 lists their core results.

Table 2 Effects of Delay of Gratification Across the Lifespan

Stage in the lifespan	**High DoG as a predictor for … / Correlations of DoG with …**
Childhood	- Attention control (Mischel, 1974) - Low DoG in children with obesity (Bonato & Boland, 1983)
Adolescence	- Intelligence (Mischel & Metzner, 1962) - Ego resilience, ego control (Funder & Block, 1989) - Inhibition, cognitive control (Eigsti et al., 2006) - Academic and social competencies, self-control, ability to pursue goals (Mischel et al., 1988) - Higher discounting rates in adolescents with Attention Deficit Hyperactivity Disorder (Scheres, Lee, & Sumiya, 2008)
Adulthood	- Students: academic performance, motivation, help-seeking, self-efficacy, task-value, goal orientation (Bembenutty & Karabenick, 1998) - Intelligence, academic achievement, need for achievement (Mischel, 1961a; Mischel & Metzner, 1962) - Hemodialysis patients: better health behavior, self-efficacy, compliance (Rosenbaum & Ben-Ari Smira, 1986) - Life satisfaction, self-worth (Rosenbaum & Ben-Ari Smira, 1986) - Higher discounting rates in pathological gamblers (Reynolds, 2006), individuals abusing alcohol and drugs (de Wit, 2009), antisocial personality disorder (Petry, 2002), obesity (Weller et al., 2008), schizophrenia (Heerey, Robinson, McMahon, & Gold, 2007), traumatic brain injury (Dixon et al., 2005), and social anxiety (Rounds, Beck, & Grant, 2007)
Old age	- Motivation regulation, optimism, facets of conscientiousness - Satisfaction with life, fewer depressive symptoms, anxiety, hostility, and perceived stress (Forstmeier et al., 2011)

Age-related Differences in Delay of Gratification

The ability of patience (e.g., delaying rewards) seems to change across the lifespan. Everyday observations show that people become increasingly patient with age: children are less willing to wait than adults, and even adolescents often react impulsively (Read & Read, 2004).

To our knowledge, the only existing study to have used a DoG measure to compare different age groups is our own (Forstmeier et al., 2011). The sample was divided into three age groups of between 60 and 94 years. There was a non-significant trend, the highest DoG being found in the group of those aged 60–69 years, and the lowest in those aged over 80 years. However, there are several studies which used a DD measure.

Comparison of Delay of Gratification across the Lifespan

Green et al. (1994) conducted the first study comparing children (mean age: 12 years), adolescents (20 years) and older adults (67 years) with regard to DD choices between immediate versus delayed hypothetical monetary rewards. The results revealed a lifespan developmental trend: the rate of discounting was highest in children (i.e., low self-control) and lowest in older adults (i.e., high self-control). This quantitative age difference in DD may be attributable to children's lack of experience with long delay, or to their greater impulsivity. The findings support the evolutionary perspective of Rogers (1994). However, Read and Read (2004) identified some limitations. First, participants came from heterogeneous backgrounds (e.g., undergraduate students versus older individuals from a study participant pool). Second, subsample sizes were quite small (12 participants per age group). Third, the researchers did not control for important influencing variables such as gender, socio-economic status, marital status, health status, etc. Most critically, there were no middle-aged participants.

Harrison, Lau and Williams (2002) estimated the DD rates of 268 Danish citizens aged between 19 and 75 years. They found a decline of DD with increasing age. Thus, they confirmed the findings of Green et al. (1994). In a further study, Green et al. (1996) explored the role of age and income in DD (using the same procedure as in their previous study). They compared three groups: 20 younger adults (upper income group; mean age: 33.3 years) and 40 older adults equally divided into upper (70.7 years) and lower income groups (70.8 years). Although the younger and older upper income groups did not differ in terms of DD, the older lower income group had higher DD rates than either the younger or the older upper income groups. Some limitations of this study need to be mentioned: small sample size, unequal distribution of men and women, exclusion of middle-aged individuals and lower income younger adults, and lack of control for influencing factors. Overall, Green at al. (1996) could not confirm a systematic decrease in DD from childhood to old age.

Read and Read (2004) identified some flaws in the pioneering study of Green et al. (1994) and tried to overcome them in a new study investigating DD across the lifespan. First, their study involved 123 participants between 19 and 89 years: not only a young (mean age: 25 years) and an old group (75 years), but also a middle-aged group (44 years). Gender distribution was also equal in all three groups, and the authors controlled for income and wealth as well as for health status and health-related behavior. Read and Read (2004) measured several dimensions of DD: first, participants had to choose between immediate smaller versus later larger hypothetical amounts of money (DD in monetary choices). The monetary rewards were fixed, but the time-spans varied (e.g., immediate versus in 1 year; in 7 versus in 10 years). Second, respondents completed a questionnaire by tapping their choices between less holiday earlier and more holiday later (DD in holidays; e.g., 1 day in one year versus 21 days in three years). Third, individuals had to choose between a sooner or later illness (DD in bouts of flu; e.g., 1-day flu immediately versus 10-day flu in 1 year). The findings demonstrated that the middle-aged group had the lowest DD rates and that the younger and older individuals discounted most in monetary and holiday choices. The findings did not support the hypothesis of Rogers (1994), but are consistent with a theory of Sozou and Seymour (2003) (see next section), according to which DoG increases until middle age, after which it decreases steadily with age.

To sum up, some authors report a curvilinear relationship between DD and age (Sozou & Seymour, 2003; Trostel & Taylor, 2001), middle-aged adults having the lowest discounting rates (high self-control) and younger and older individuals having higher rates (low self-control). Early in life, DD rates are high because the environment still has to be explored and the future is uncertain. In later life, the future again becomes insecure and risky as diverse capacities decline. Relative to Trostel and Taylor (2001) the model of Sozou and Seymour (2003) hypothesizes a steeper decrease in discounting rates from the age of 40. Both theories are inconsistent with the hypotheses of Rogers (1994), who predicts a linear decrease in DD across the lifespan, with no middle-age peak. Taken together, the hypotheses of Trostel and Taylor (2001) and of Sozou and Seymour (2003) are not independent (Read & Read, 2004). For instance, the age-related decline in fertility may affect the expectancy of enjoying the pleasure of delayed rewards in the future.

Time Perspective and Subjective Life-expectancy—Contribution to Evolutionary Theories

Green et al. (1996) proposed that DoG may become less important as people increasingly see their life expectancy as limited. Although the authors compared various age groups, they did not include measures of subjective life expectancy. As such, they could not analyse this potentially important influencing factor. Time-perspective, a fundamental component in the construction of psychological time, is the result of cognitive processes which divide one individual's experience into past, present, and future temporal frames (Boyd & Zimbardo, 2005). Subjective life expectancy is the number of years an individual expects to live (Ross & Mirowsky, 2002).

Some humans are predominantly present-oriented, others are primarily future-oriented. The former prefer immediate gratification and have less impulse control. The latter focus on delayed gratification—they make choices based on the estimated cost/benefit ratio of a future pleasure or action. They are also better able to control their impulses (Zimbardo & Boyd, 1999).

Socio-emotional selectivity theory (Carstensen, Isaacowitz, & Charles, 1999) postulates that individuals focus more on the present and less on the future when they realize that the rest of their life is limited. Thus, instead of future payoffs, they focus on making the right choices now. This influences both their decisions and their actions, as they pay more attention to subjective and intuitive aspects (Reynolds et al., 2002). The prioritization of immediate versus delayed rewards thus changes with age. If older adults are unsure whether they will benefit from delayed rewards in the future, because they feel that time is running out, they may well favor a certain reward in the present. Behavioral economic models support these ideas: older adults seem to take their subjective life expectancy (number of remaining years) into consideration in economic decision processes. Greater rates of delay discounting are reported in older adults because increasing age implies a higher risk of not surviving to collect a delayed reward (Carstensen et al., 1999).

Steinberg et al. (2009) focused on age-related differences in future orientation and DD in individuals aged between 10 and 30 years. Future orientation subsumes cognitive, motivational, affective, attitudinal and evaluative constructs, including time-perspective and the degree to which individuals think about their future lives or imagine possible future circumstances (Cauffman & Steinberg, 2000; Greene, 1986). The authors measured DD with a monetary choice procedure and future orientation with a newly developed scale (see Table 1). The results showed that adolescents aged between 10 and 13 years describe a weaker future orientation than participants aged 16 and older. First, they more often prefer smaller and sooner to delayed, larger rewards. Second, they describe themselves as less concerned about their future and less likely to anticipate the consequences of decisions. Surprisingly, future orientation and not impulsivity (measured with the Barratt Impulsiveness Scale; see Table 1) significantly mediated the age differences in DD.

Conclusions

Clinical Implications

DoG is an important predictor of various cognitive abilities, motivation to change, health behaviors, and wellbeing. With respect to health behavior, DoG plays a decisive role in, for example, the decision to abstain from excessive sunbathing in order to reduce the risk of contracting skin cancer in old age or to engage in regular exercise to keep fit and healthy. DoG may also be essential in maintaining health behavior—a fact which may exploited by programs promoting health-related behavior. In addition, DoG is not only important in the field of primary prevention. The success of secondary and tertiary prevention also depends on self-regulated behavior—for example, in minimizing the negative effects of chronic diseases such as rheumatism, hypertonia, diabetes, HIV and COPD. In sum, compliant behavior reduces costs for social insurance systems.

Reasons for Lack of Delay of Gratification Studies in Adulthood and Old Age

Why have DoG studies to date largely neglected adulthood and old age? One possible answer is simply that the original continuous measure of DoG is only suitable for children. Mischel’s original DoG paradigm (the “marshmallow test", Goleman, 1995) is of limited, if any, value for studies with adolescents and adults, because the delay intervals were adapted to children’s experience and perception of time, and thus span only a few minutes. In contrast, studies with adults require both meaningful DoG intervals (days or weeks) and meaningful rewards. Assessment of DoG by self-report questionnaires may produce biased results, due to the problem of social desirability (Wulfert et al., 2002). It is only recently that an age-appropriate DoG test has been developed by the present authors (Forstmeier et al., 2011).

Several studies have focused on DD from childhood to old age, most of them using hypothetical monetary choice procedures which have gained broad acceptance in psychological and economic research. Although DoG is a multidimensional construct (Bembenutty & Karabenick, 1998; Ward et al., 1989) which may differ from domain to domain, it is still unclear whether low DD rates imply a general preference for delayed rewards. In fact, in a study with the newly developed DoG test, the snacks score proved to be the best indicator of wellbeing, although the various reward types had low-to-medium intercorrelations. By the same token, a factor analysis in a study with college student leaders showed that DoG could be divided into dimensions such as achievement orientation and career objectives (Ward et al., 1989). Similarly, the concept of academic DoG limits DoG to that context (achievement of academic rewards). Experimenters must also bear in mind that DoG is highly dependent on the situation (e.g., Metcalfe &

Mischel, 1999). Nevertheless, a general factor of DoG may also make sense, because individuals can potentially exhibit high DoG in many dimensions. For example, one individual may show high academic DoG and high DoG in health behavior. Moreover, there is little evidence to support the idea of DoG as an ability which is both learned and generalized across situations (Eisenberger & Adornetto, 1986). Several authors have emphasized that the DD task is an indicator of actual decisions, as DD rates do not differ between real and hypothetical monetary rewards (Johnson & Bickel, 2002; Lagorio & Madden, 2005; Madden et al., 2003).

Another reason for the neglect of DoG studies in adulthood may be that self-regulation can easily be measured with self-report questionnaires such as the Volitional Components Inventory (VCI; Kuhl & Fuhrmann, 1998), Short Self-Regulation Questionnaire (SSRQ; Neal & Carey, 2005), Brief Self-Control Scale (BSCS; Tagney et al., 2004) or Barratt Impulsiveness Scale (Patton et al., 1995). Executive functions have also been broadly examined in impaired and unimpaired older adults. Diverse measures are applicable, depending on the domain of executive functioning: for example, task switching (Trail Making Test - Part B; Reitan, 1958) or inhibition of predominant responses (Stroop Color-Word Test; Stroop, 1935).

Does the Ability to Delay Gratification Decrease or Increase with Age?

On one hand, the ability to self-regulate seems to be stable across the lifespan (Wulfert et al., 2002). Some authors have suggested that DoG likewise takes shape in childhood and remains robust in later life (Funder & Block, 1989; Kirby et al., 2002; Rosenbaum & Ben-Ari Smira, 1986). On the other hand, changes in the ability to delay gratification across the lifespan are obvious and observable in everyday life: young children are more impulsive and impatient, whereas adults and older individuals are more patient, better able to resist their impulses, and more willing to wait (Read &

Read, 2004). In other words, possible long-term consequences weigh more heavily and seriously for adults. Neuropsychological evidence supports these ideas: the frontal lobe regions ("cold" system) mature as children grow up, whereas the "hot" system is already fully developed (Altman & Bayer, 1990). However, as older individuals become aware of the limited time available to them, they may come to behave "like there's no tomorrow" (Green, Myerson, Lichtman, Rosen, & Fry, 1996). Thus, the variables of time-perspective and subjective life expectancy give new impetus to evolutionary theories, and may help to explain why DoG may decrease in adulthood and old age. In addition, neuropsychological evidence suggests that DoG may decrease in both unimpaired and impaired older adults—for example, in individuals with dementia, a disease with dramatically increasing prevalence rates (Ferri et al., 2005). Empirical findings point to relations between executive functions, DoG, and frontal functioning (Cheung, Mitsis, & Halperin, 2004; Spinella, 2004; Stuss & Levine, 2002).

In normal aging, there is a neural loss in the prefrontal cortex (Ropper & Samuels, 2009; Zatz, Jernigan, & Ahumada, 1982). Neuropsychological behavioral evidence also describes a decline in executive functions with advancing age (e.g., Mittenberg, Seidenberg, O'Leary, & DiGiulio, 1989). Individuals with dementia also have significantly more deficits in executive functions than unimpaired controls (e.g., Lafleche & Albert, 1995). In sum, there is a need for validated DoG measures for application in adults.

Potential Future Studies of Delay of Gratification

First, longitudinal analyses could investigate stability versus changes in DoG across the lifespan. Second, the possible protective effects of DoG on health, wellbeing and satisfaction with life in adulthood and old age warrant more detailed investigation.

Third, further studies should examine whether DoG helps to protect against cognitive decline. Specifically, high DoG may result in high cognitive and motivational reserves. Whereas cognitive reserve helps the human brain to cope with impairment through activation of pre-existing cognitive resources and compensatory mechanisms (Stern, 2006), motivational reserve refers to motivational aspects of cognitive aging. For instance, individuals with high DoG across the lifespan may show higher educational and occupational attainment—two indices of cognitive reserve (Stern, 2006). DoG is a behavioral measure of motivational abilities which are discussed as protective factors in emotional and cognitive health (Forstmeier & Maercker, 2008). Fourth, the neural substrates of DoG are also worth exploring. Structural MRI studies could further examine the relationship between DoG and the frontal lobes. Functional MRI studies could contribute to elucidating activation patterns in decisions for immediate versus delayed rewards.

Lastly, as difficulty in delaying gratification and self-regulating is seen as maladaptive, immature and irrational (e.g., Green et al., 1994), implications for practice include the development of interventions to enhance DoG. Inasmuch as DoG is a crucial ability associated with numerous competencies and qualities, various open questions warrant investigation here. For example, research could explore the benefits of DoG modifications in different age groups and as a predictor of diverse outcomes across the lifespan.

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Paper 2: SOEP Children's Study: Interactions of Cognition, Education, and Personality in Decisions between Immediate and Delayed Rewards in Mothers and their Children

(Drobetz, Maercker, Spiess, Wagner, & Forstmeier, submitted)

Abstract

Delay of gratification (DoG) refers to the preference for delayed larger instead of immediate smaller rewards. Delay Discounting (DD) covers the devaluation of a gratification over time. Above all, cognitive and personality variables explain individual differences in both constructs; however there is a lack of studies exploring interactions of variables in DoG and DD decisions. The present study measured DD in 291 mothers and DoG in 270 children and assessed cognitive abilities, education and personality traits. Children with higher verbal intelligence and higher prosocial behavior / agreeableness had higher DoG. In mothers, education and agreeableness significantly interacted in predicting DD. Future studies should consider these variables, and verbal (over fluid) intelligence for individual's differences in DoG and DD.

Keywords: delay of gratification, delay discounting, education, cognition, personality, SOEP

Introduction

Individuals have to deal with choices between immediate and delayed rewards continuously across the lifespan. For instance, children have to wait several weeks until Christmas for their gift wishes to come true, and those who no longer believe in Santa Claus have to decide between searching for the hidden presents in drawers and cupboards and waiting until their parents lay them under the Christmas tree. Dieting adults, for instance, have to delay eating tasty and caloric food in order to slim down. And, for example, adults have decide between saving money for their children or for hard times versus satisfying their immediate needs in terms of shopping.

Delay of gratification (DoG) is the rejection of immediate tempting rewards for the sake of later and better rewards (Mischel et al., 1989; Witt, 1990). Delay discounting (DD; Green et al., 1994), a similar concept, refers to the decrease of the subjective value of a future reward with increasing delay interval (Kirby et al., 1999). Both DoG and DD are facets of self-regulation, i.e. the altering of behavior for the pursuit of specific goals (Baumeister et al., 2007). It should be noted that low DD means high DoG or high self-regulation. Further, the emergence of self-regulation at around the age of three is one of the most important developmental steps in childhood (Kopp, 1982; Vaughn, Krakow, & Kopp, 1984).

In a nutshell, reward research differentiates between primary rewards (e.g. food, water or sexual stimuli) and secondary rewards (e.g., money or cultural goods such as labels or music) (Walter et al., 2005). Studies in children predominantly use primary rewards: In the original DoG experiment the participating child has to decide between one marshmallow now or two marshmallows later (Mischel, 1974). In contrast, DD studies in adults commonly use real or hypothetical monetary rewards (secondary reinforcers), e.g. “Would you prefer $25 today, or $60 in 14 days?”(Kirby et al., 1999).

Studies primarily assess DoG and DD using behavioral tests compared to e.g. self-reported self-regulation.

Background

Self-Regulation and Cognitive Abilities

Mischel and Metzner (1962) found a significant positive relationship between 5-12-year-old children's DoG and intelligence (IQ). Moreover, with advancing age, children became increasingly willing to postpone the immediate incentives. Learning to delay gratification goes along with learning to think (Mischel & Metzner, 1962). In detail, instead of impulsive motor discharge, children learn to use cognitive reality testing (Rapaport, 1950). Beyond this, the preference for a delayed reward is also a predictor of long-term intelligence outcome and cognitive competencies in adolescence (Mischel & Metzner, 1962; Mischel et al., 1988; Shoda et al., 1990).

A meta-analysis showed that individuals with higher intelligence had significantly lower DD rates (Shamosh & Gray, 2008). Intelligence remained a significant predictor of DD in adults, even when controlling for socio-economic status, age or education (de Wit, Flory, Acheson, McCloskey, & Manuck, 2007).

Strong relations might exist between verbal intelligence and DD. Specifically, individuals with higher verbal intelligence might be better able to overvome the temptation of the immediate incentive through the so-called strategy of cognitive reappraisal, i.e. individuals' often verbally driven reinterpretation of the meaning of a significant stimulus (Gross, 2001; Ochsner et al., 2002). A longitudinal study supported the described link: The longer preeschoolers had been able to wait for a gratification, the higher was their score in verbal fluency in adolescence (Mischel et al., 1988). DD might also be simply associated with general cognitive abilities (Hirsh, Morisano, &

Peterson, 2008). In a meta-analysis, Shamosh and Gray (2008) were unable to find moderator effects of the type of intelligence in DD tasks. However, the researchers criticize the insufficient labelling of the type of intelligence depending on the available information of the analyzed studies. Thus, they suggest including measures of both fluid and verbal intelligence in future DD studies.

Self-Regulation and Education

DoG in children is a predictor of need for achievement and SAT (Scholastic Aptitude Test) scores in adolescence (Mischel, 1961b; Shoda et al., 1990), which can be seen as indicators of higher education. Moreover, students' higher academic DoG results in better academic performance (Bembenutty & Karabenick, 1998). Pressley, Reynolds, Stark and Gettinger (1983) emphasized the importance of DoG for education, academic achievement, and academic performance. As DoG can foster learning as well as information processes, individuals should endeavour to enhance their DoG (e.g. through DoG training) (Pressley et al., 1983).

A negative correlation was found between DD and college grade point average (Kirby, Winston, & Santiesteban, 2005). Likewise, a study in smokers revealed a negative relation between education and DD (Jaroni, Wright, Lerman, & Epstein, 2004). De Wit et al. (2007) found an inverse relationship between DD and education; however, personality and intelligence mediated this effect.

Self-Regulation and Personality

While various studies have explored the link between cognitive abilities and DoG / DD, only a small number have focused on the relationship between personality and DoG / DD (Hirsh et al., 2008). There is scientific consensus regarding DD procedures as a measure of impulsivity (e.g. Bickel, Odum, & Madden, 1999). In children, high DoG has been linked with social responsibility (Mischel, 1961b) and prosocial behavior (Long & Lerner, 1974). Furthermore, the number of seconds for which preschoolers were able to wait for a specific reward was found to be a predictor of social competencies when they reached adolescence (Mischel et al., 1988).

A study in 13- and 14-year-old boys demonstrated that the teenagers with high DoG scored significantly higher in caregivers' ratings of the Big Five personality traits openness, conscientiousness, and agreeableness (Krueger et al., 1996). With respect to DD, evidence suggests that adults with higher Extraversion have significantly higher DD rates (Ostaszewski, 1996).

Interactions of Variables in Self-Regulation

Although numerous studies have explored the relationship between cognitive abilities and DD (for a meta-analysis see Shamosh & Gray, 2008), there is a lack of specific studies examining personality traits and DD as well as interactions of cognition, education and personality in DD and DoG. Hirsh, Morisano and Peterson (2008) investigated the role of the Big Five personality traits and general cognitive ability as predictors of DD in undergraduate students. They found that extraverted students with lower levels of cognitive ability had higher DD rates. In contrast, students with higher emotional stability and higher levels of cognitive ability showed lower DD rates (Hirsh et al., 2008). Although their pioneering study contributes to our understanding of the interaction between personality traits and cognitive ability in DD behavior, the authors discuss some limitations. Most critically, the measures only included a proxy for general cognitive ability, without differentiations between fluid intelligence (e.g. perceptual speed) and verbal intelligence.

In a recent paper, we explored intergenerational links and maternal antecedents in children's self-regulation using the SOEP children's study. We found a low (but not significant) correlation between children's DoG and maternal DD, and discussed possible differences between DoG and DD. As mentioned above, using a different research question and approach, we now further explore possible interactions of variables in DoG and DD.

Aims of the Present Study

The main aim of the present study was to explore interactions of variables in children's DoG and mothers' DD. This is an important research question because study findings demonstrated links between high self-regulation and high wellbeing as well as high life satisfaction (Kruglanski et al., 2000; Rosenbaum & Ben-Ari Smira, 1986; Tagney et al., 2004). In light of previous findings, we predicted that cognitive abilities and education would be moderators of the relationship between personality variables and delaying behavior. In detail, Big Five personality traits such as agreeableness and strengths such as prosocial behavior would be stronger predictors of children's DoG at the higher end of cognitive abilities and education. Likewise, we hypothesized interactions of cognitive abilities, education and personality in DD decisions. For instance, individuals with high agreeableness or high openness and high education would show lower DD. Further, this study questioned whether the strength of association between fluid and verbal intelligence and DoG or DD differed. Additionally, the samples enable an intergenerational comparison, e.g., whether cognitive abilities and Big Five personality traits relate to DoG / DD in mothers and children.

Method

The present analysis used data of the German Socio-Economic Panel (SOEP) children's study. The SOEP conducted the SOEP children's study, which is a related study to the well-known SOEP, in 2008 (Wagner, Frick, & Schupp, 2007). Please see Siegel, Jänsch and Stimmel (2008) for more details on this data set.

Study Participants

All participants were part of the SOEP children's study recruited by TNS Infratest, the fieldwork institute running the SOEP study. The original sample consisted of 291 mothers and their children. The SOEP children's study used gummy bears as rewards to measure children's DoG. 19 children had to be excluded as their mothers said that they would rather not, or not at all, like to eat gummy bears. This is important since study findings suggest that DoG experiments have to use attractive and real incentives for individuals in order to evoke their motivation (Wulfert et al., 2002). Two children who were unable to understand the instructions despite repeated explanations were not considered in the data analysis.

Therefore, the final subsample of children consisted of 270 participants, whereas the subsample of mothers comprised 291 individuals. The mothers' mean age was 36.3 years (SD = 5.4), ranging from 24 to 58 years, and the children's mean age was 72.1 months (SD = 6.7), with a range from 61 to 84 months (between 5 and 6 years). 44% of the sample of children were girls.

Materials in Children

Delay of gratification. The so called behavioral gummy bear experiment measured DoG in children using organic gummy bears following the classic "marshmallow test" (Mischel et al., 1989). The study used one versus two packs of gummy bears as primary reinforcers. After opening one pack, the experimenter placed it together with the second closed pack clearly visible on the table in front of the child. Subsequently, the experimenter informed the child that if he/she wanted gummy bears during the interview with the mother, he/she could grab the sweets from the opened pack and eat them. However, the child would then only get the opened pack. If the child did not eat any gummy bears until the interview with the mother was over, he/she would get the opened and the closed pack as a present. The experimenter did not let the child know how long the interview with the mother would definitely last. Additionally, the experimenter ensured that the child had actually understood the instructions and repeated them if necessary.

Fluid intelligence. The Culture Fair Intelligence Test (CFT 1; Cattell, Osterland, & Weiss, 1997) is a measure of intelligence (perception of relationships in shapes and figures) using non-verbal, culture-fair items. Subtests 3 (classifying) and 5 (solving matrices) were used in this study. Whereas in subtest 3 the children have to find the distracter (one picture that does not fit to the others) among 5 pictures, in subtest 5, their task is to cross 1 item out of 5 that completes a given pattern. We calculated a composite score for fluid intelligence.

Verbal intelligence. A German 61-item short version of the Peabody Picture Vocabulary Test (PPVT) (Dunn & Dunn, 1997; Rossbach et al., 2005) was used to assesses verbal intelligence., i.e. receptive vocabulary indicating the children’s acquisition of language. Each item consists of 4 pictures. After the experimenter states a noun, verb or adjective (e.g. penguin, decorating, surprised etc.), the child has to point to the correct picture representing the word.

Strengths and difficulties. Several versions exist of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997, 2001) ; however, the current study used a 25-item version for children between 4 and 10 years of age. The SDQ has 5 subscales, namely 1. emotional problems, 2. conduct problems, 3. hyperactivity / inattention, 4. peer relationship problems and 5. prosocial behavior. The Total Difficulties Score consists of all scales except for prosocial behavior. Mothers rated the behavior of their child under consideration of the last 6 months on a 3 point-scale e.g. “My child…is considerate of other people’s feelings”.

Big Five personality traits. Mothers rated their child’s Big Five personality traits extraversion, conscientiousness, agreeableness, openness, and emotional stability (Asendorpf, 1998; Asendorpf & Van Aken, 2003). Specifically, they judged their child compared to other children of the same age by means of 10 bipolar adjective pairs (e.g. communicative – quiet) on 11-point scales.

Education. Children in kindergarten or at home (3 children) were dichotomized as 0, children in school as 1.

Materials in Mothers

Delay discounting. The SOEP children’s study measured DD using a behavioral procedure developed by Dohmen, Falk, Huffman and Sunde (2007) in the context of SOEP. Participants had to make choices between two hypothetical monetary rewards in Euros (1 Euro equals approximately 1.4 US Dollars) presented in rows of a 20-column table. In each row, individuals had to state whether they would prefer the small immediate amount of money in A or whether they would take the larger delayed reward. If they chose the later larger amount of money, the interviewer stopped the procedure. Specifically, participants had to choose between a fixed 100€ now (A) and a successively increasing amount of money in 6 months (B; row 1 – row 20: 101.20 – 124.80€). We converted the amount of money in row B into delay discounting rates (*k*) in order to gain a measure of DD comparable with other studies. For each study participant, *k* was calculated using this formula (Kirby et al., 1999):

DD: $k = \log\,[(B/100 - 1) / 6]$ with B = larger delayed amount of money in row B. A higher *k* means greater DD behavior and therefore lower self-regulation.

Fluid intelligence. The fluid intelligence was measured using a modified computerized version of the Digit Symbol Test (C-DST) of the Wechsler Adult Intelligence Scale – Revised (Wechsler, 1981). The C-DST assessed perceptual motor speed and incidental learning with digit-symbol pairs from 1 to 9, e.g. 1/- or 8/X. The mothers had to type the correct digit (using the keyboard of a notebook) under each given symbol. In both versions of this speed test, the task has to be completed as quickly as possible in a given time (C-DST: 90 seconds). In the C-DST, participants saw only one symbol on the notebook monitor; after typing the digit, the next symbol appeared.

Verbal intelligence. The Multiple-Choice Vocabulary Test (MWT; Lehrl et al., 1995), a 37-item questionnaire, was used to measure verbal intelligence. Each line of the MWT consists of four invented distracters and one real, correct piece of vocabulary. According to the instructions, mothers crossed out the word that was to their knowledge the real one in each line.

Big Five personality traits and personality domains. Study participants rated their Big Five personality traits with the 15-item self-report questionnaire Big Five Inventory-SOEP (BFI-S; Lang, John, Lüdtke, Schupp, & Wagner, 2011; Schupp & Gerlitz, 2008). The BFI-S covers extraversion, conscientiousness, agreeableness, openness, and 5. neuroticism (emotional stability). The mothers rated statements such as “I am somebody who has a lively and active imagination” (openness) on a 7-point scale.

In addition, mothers rated themselves on 11-point scales in terms of their strength of agreement with the following items: 1. impulsivity (not impulsive at all – very impulsive), 2. patience (very impatient – very patient), 3. readiness to assume risk (not at all prepared to take risks – very prepared to take risks) and 4. life satisfaction (overall satisfaction with life at the moment).

Education and household income. On the one hand, maternal education was assessed as the sum of years of education. On the other hand, the mothers told the interviewers the monthly net household income (in Euros). These questions are well established in the main SOEP, which runs since 1984.

Procedure

Trained interviewers collected data of children and mothers at the family's home. The experimenters explained the aims of the study and obtained informed consent. Subsequently, the gummy bear experiment began, with mother and child in the same room. During the exposure of the child to the gummy bears, mothers had to answer questions. Before the measurement of mothers' DD behavior, the delaying children received the second pack of gummy bears. Finally, the mothers received a lottery ticket for their study participation.

Data Analysis

For the data analysis, we used SPSS Statistics 19 (Statistical Package for the Social Sciences, IBM). Correlation analyses explored relationships between cognitive abilities, personality traits and DoG and DD. In order to answer the question of which variables are significant predictors of self-regulation, we used binary logistic regression analysis for DoG and multiple linear regression analysis for DD. We entered all children's variables of interest into a model predicting DoG and all maternal variables of interest into a model predicting DD. The variables were chosen with respect to previous significant findings, e.g. gender differences in DoG (Silverman, 2003), relationship between self-regulation and well-being / life satisfaction (e.g., Kruglanski et al., 2000) or the inverse relationship between household income and DD (Green et al., 1996).

In order to examine interactions between cognition, education, and personality in the DoG behavior of children, a binary regression analysis was conducted. In the first model (method: forward likelihood ratio), we entered variables of interest and interaction terms. In the second model (method: forward likelihood ratio), we included significant variables in the model predicting children's DoG.

To explore possible interactions between cognitive abilities, education and personality traits in DD choices of mothers, we conducted a multiple linear regression analysis. In the first model, predictors that proved to be significantly correlated with DD were entered. We added interaction terms of significant variables into the second model predicting DD.

Results

Self-Regulation in Children

Delay of gratification. 211 of 270 children (78.2%) waited for the second pack of gummy bears (DoG children). 59 children (21.8%) ate gummy bears from the first pack and were unable to wait for the second (Non-DoG children). In Non-DoG children, the mean time until they ate the gummy bears was M = 7.8 seconds (SD = 10.2, Minimum = .1, Maximum = 44.9).

Table 3 shows the correlations between variables of interest and children's DoG. In the subsample of 59 Non-DoG children, the correlations between the time until the child ate the gummy bears (in minutes) and the Big Five personality traits Extraversion ($r = -.31$, $p < .05$) as well as openness ($r = -.30$, $p < .05$) were negative and significant.

Table 3 Delay of Gratification in Children: Association of Cognitive Abilities, Personality Traits, and Strengths and Difficulties with Summary of the Binary Logistic Regression Analysis (N = 270)

Variables	*r*	*B*	*SE B*	*Odds ratio*	*.95 confidence interval*	
					lower limit	*upper limit*
Demographic variables						
Age (in months)	.16**	.04	.03	1.04	.99	1.10
Gender (reference: female)	-.01	.16	.33	1.18	.62	2.24
Cognitive abilities						
Fluid intelligence	.01	-.05	.04	.95	.88	1.03
Verbal intelligence	.12*	.03	.02	1.03	.98	1.08
Strengths and Difficulties						
Total Difficulties Score	-.07	.11	.13	1.12	.87	1.44
Prosocial behavior	.29***	.40	.12	1.49***	1.18	1.88
Big Five personality traits						
Extraversion	-.31*	.08	.05	1.08	.98	1.19
Conscientiousness	.10	.01	.05	1.01	.92	1.12
Agreeableness	.14*	.05	.05	1.05	.96	1.16
Openness	.10	.01	.06	1.01	.89	1.14
Emotional stability	.07	-.05	.05	.95	.87	1.04

*$p < .05$, **$p < .01$, ***$p < .001$

Note. Binary logistic regression, method: Enter. r = correlation coefficient (point biseral correlation), B = regression coefficient, *SE B* = standard error of regression coefficient. Nagelkerke's R^2 (coefficient of determination) = .12 ($p < .001$). Gender is a categorical variable, reference = females (1).

Predictors of delay of gratification. Table 3 summarizes the results of a binary logistic regression analysis. When we controlled for sociodemographic variables, cognitive abilities and personality traits, prosocial behavior was the best predictor of children's DoG, *Odds ratio (OR)* = 1.49, p < .001. Taken together, the predictors explained 12% of the variance, R^2 = .12, *OR = 3.58, p* < .001.

Interactions of variables in delay of gratification. As shown in table 4, in the first regression model, prosocial behavior and verbal intelligence interacted significantly in predicting DoG even when controlling for age, *OR* = 1.01, p < .001.The predictors explained 16% of the variance, R^2 = .16, *OR* = 3.58 (p < .001). In the second model, agreeableness × verbal intelligence (*OR* = 1.00, p < .05) and age (*OR* = 1.05, p < .05) significantly predicted children's DoG. In this case, the predictors explained 10% of the variance, R^2 = .10, *OR* = 3.58, p < .001.

Table 4 Delay of Gratification in Children: Interaction of Variables (N = 270)

Variables	*B*	*SE B*	*Odds ratio*	*.95 confidence interval*		
				lower limit	*upper limit*	R^2
Model 1						.16
Age	.05	.02	1.05	1.00	1.09	
Prosocial behavior × verbal intelligence	.01	.00	1.01***	1.00	1.01	
Model 2						.10
Age	.06	.02	1.05*	1.01	1.10	
Agreeableness × verbal intelligence	.00	.00	1.00*	1.00	1.00	

*p < .05, ***p < .001

Note. Binary logistic regression analysis. *B* = regression coefficient, *SE B* = standard error of regression coefficient. R^2 = Nagelkerke's coefficient of determination (p < .001).

Self-Regulation in Mothers

Delay Discounting. The correlations between variables of interest and maternal DD are shown in table 5. In the subsample of mothers, no significant correlation existed between age (in years) and DD (r = -.00, p = .95). We further found a significant negative correlation between education and impulsivity (r = -20, p < .01), and a significant positive correlation between education and openness (r = .25, p < .001).

Table 5 Delay Discounting in Mothers: Association of Cognitive Abilities, Education, and Personality (N = 291)

Variables	*r*	*B*	*SE*	*ß*
Socio-demographic variables				
Education (in years)	-.20**	-.03	.05	-.06
Monthly net household income	-.13	3.91	.00	-.05
Cognitive abilities				
Fluid intelligence	-.01	.01	.01	.05
Verbal intelligence	-.13*	-.03	0.02	-.09
Big Five personality traits				
Extraversion	-.03	.01	.02	.02
Conscientiousness	-.03	.01	.03	.02
Agreeableness	.14**	.06	.03	.18*
Openness	-.10	-.02	.02	-.08
Emotional stability	.05	.02	.02	-.07
Personality Domains				
Impulsivity	-.05	.01	.04	.03
Impatience	.11	.04	.03	.11
Readiness to assume risk	-.02	.01	.03	.03
Life satisfaction	-.16**	-.12	.04	-.23**

*$p < .05$, **$p < .01$

Note. Multiple linear regression analysis. *r* = Pearson / Spearman correlation coefficient, *B* = regression coefficient, *SE* = standard error of regression coefficient, *ß* = beta coefficient, R^2 (coefficient of determination) = .15 ($p < .001$).

Predictors of delay discounting. As shown in table 5, agreeableness significantly predicted DD, $b = .06$, $t(210) = 2.22$, $p < .05$. In addition, life satisfaction proved to be a significant predictor of DD, $b = -.12$, $t(210) = -2.93$, $p < .01$. The predictors explained 15% of the variance, $R^2 = .15$, $F(13, 210) = 1.97$, $p < .05$.

Interactions of variables in delay discounting. Table 6 summarizes the results of a regression analysis including the interaction of relevant variables. With respect to significant interactions, education and agreeableness significantly interacted in predicting DD, $b = -1.05$, $t(210) = -1.98$, $p < .05$. All predictors explained 10% of the variance, $R^2 = .10$, $F(9, 277) = 3.30$, $p < .01$.

Table 6 Delay Discounting in Mothers: Interaction of Variables (N = 291)

	B	*SE*	*ß*	R^2
Model 1: Significant Variables				.08
Education (in years)	-.08	.06	-.09	
Verbal intelligence	-.07	.06	-.07	
Agreeableness	.17	.06	.17**	
Life satisfaction	-.17	.06	-.18**	
Model 2: Variables and Interactions				.10
Education (in years)	.90	.38	.95*	
Verbal intelligence	-.54	.33	-.54	
Agreeableness	.41	.52	.43	
Life satisfaction	.28	.62	.29	
Education × agreeableness	-1.05	.53	-1.11*	
Verbal intelligence × agreeableness	.73	.63	.77	
Education × life satisfaction	-.58	.50	-.62	
Verbal intelligence × life satisfaction	.10	.58	.11	
Agreeableness × life satisfaction	-.08	.43	-.08	

*$p < .05$, **$p < .01$

Note. Multiple linear regression analysis. *B* = regression coefficient, *SE* = standard error of regression coefficient, *ß* =beta coefficient, R^2 = coefficient of determination ($p < .001$).

Discussion

Self-Regulation in Children

The data analysis showed that children are better able to delay the offered gummy bears with increasing age. Therefore, we were able to support the link between age and DoG (e.g., Metcalfe & Mischel, 1999; Steinberg, 2007), which also demonstrates that the gummy bear experiment is a valid and reliable way of assessing DoG in today's children. Further, we were able to confirm the strong link between prosocial behavior and DoG in a regression analysis even when controlling for confounding variables such as age (e.g., Funder & Block, 1989; Long & Lerner, 1974).

Interestingly, the higher the Extraversion of Non-DoG children, the lower the maximum amount of time they waited to eat the gummy bears turned out to be. This result reflects previous findings in DD of adults (e.g., Ostaszewski, 1996). In contrast, children with higher ratings on Extraversion were significantly better able to delay gratification. Although this is in contrast to past studies in adults (Ostaszewski, 1996), there is a least one explanation for this surprising result: An interesting approach comes from Metcalfe and Mischel (1999), who explain processes in DoG with interactions of the "hot" and "cool" system. Whereas the "hot" system refers to affective and motivational aspects which impede attempts to exert self-control, the "cool" system relates to flexible cognitive and emotionally neutral aspects. Successful DoG is the result of effective inhibition of the "cool" system over the "hot" system, the antagonists of self-regulation. From the perspective of Developmental Psychology, the "hot" system develops early in a human's ontogenesis and is dominant in childhood, while the "cool" system gains increasingly in strength in young adulthood (Metcalfe & Mischel, 1999; Zelazo et al., 2005). Given this theory, Extraversion might not be the explaining factor for children's DoG. Rather, the development of children's "cool" strategies and the successful transformation and inhibition of the “hot” aspects might predominantly account for children’s DoG.

Self-Regulation in Mothers

Agreeableness and life satisfaction were significant predictors of maternal DD (even when controlling for various variables). However, higher agreeableness was linked with higher DD, which is in contrast to previous findings (e.g., J. D. Miller, Lynam, & Jones, 2008). The present study also failed to find a link between DD and conscientiousness. As low agreeableness covers, among other things, distrust, deception, hostility etc. (J. D. Miller et al., 2008). Why did the present study reveal a low but significant positive correlation between agreeableness and DD? The BFI-S only includes socially acceptable facets of agreeableness, e.g. “I treat other people with respect and friendliness”. Mothers who are highly socially agreeable might not necessarily delay monetary rewards, as delaying money is a special facet of self-regulation. Besides, the subjective value of a reward influences choices between immediate and delayed rewards (e.g., Mischel, 1974). Furthermore, socially agreeable individuals might focus on well-functioning social relationships and also have high empathy (Kirby et al., 1999; J. D. Miller et al., 2008). Thus, money might not be so important to them and they might rather delay gratification in order to fulfill the needs of others.

Low DD (i.e., high self-regulation) might buffer against lower life satisfaction. Conversely, individuals with high life satisfaction might have a lower tendency to need to satisfy immediate impulses. Indeed, hemodialysis patients aged with higher DoG reported higher self-worth and life satisfaction (Rosenbaum & Ben-Ari Smira, 1986). Furthermore, a recent study in the elderly showed that high DoG was a significant predictor of wellbeing (Forstmeier et al., 2011). Thus, we conclude that the link between self-regulation and life satisfaction might be crucial for different age groups across the lifespan.

Individuals with low education preferred immediate incentives to a significantly higher degree, supporting previous findings (Jaroni et al., 2004; Merrell & Tymms, 2001; Miley & Spinella, 2003; Petry, Kirby, & Kranzler, 2002).

Comparison of Children's and Mothers' Self-Regulation

An advantage of the study might be the use of both primary (i.e., food in children) and secondary reinforcers (i.e., hypothetical monetary rewards in mothers). These different experimental paradigms enable comparisions of the outcome of both samples. Children and mothers with high verbal intelligence seemed to overcome the temptation of both primary and secondary reinforcers more efficiently. In contrast, there were no significant correlations between fluid intelligence and self-regulation in both samples. Taken together, the presented study supports the assumption that verbal intelligence is one of the major contributors to successful self-regulation (e.g., Shoda et al., 1990). We explain this finding by the better verbally driven reinterpretation of the rewards by children and mothers with higher verbal intelligence (Ochsner et al., 2002). Verbal capacities might also contribute to better cognitive distraction by making the (verbal) focus on other stimuli easier (e.g., Mischel, 1974). Further, verbal intelligence, often termed as crystallized intelligence, can be defined as "the extent to which a person has absorbed the content of culture." (Belsky, 1990, p. 125). Indeed, individual differences in DoG are also explained by socialization or cultural processes (Wulfert et al., 2002).

Mothers with low agreeableness preferred the delayed rewards to a significantly greater extent. In contrast, children with higher agreeableness had higher DoG, supporting the link between social competencies and self-regulation (e.g., Mischel et al., 1988). However, children had to choose between primary rewards, while the sample of mothers used secondary rewards. Besides, the subjective value of the gummy bears for children might have been higher when compared to hypothetical money for mothers as only children who rather liked, or very much liked, gummy bears were included.

Interactions of Cognition, Education and Personality in Self-Regulation

Children with higher verbal intelligence and higher prosocial behavior had higher DoG. As high social responsibility and high prosocial behavior as well as higher verbal capacities relate to high DoG (Long & Lerner, 1974; Mischel, 1961b; Mischel et al., 1988), it makes sense that individuals with high values both in prosocial behavior and in verbal intelligence benefit in DoG decision processes. This pattern could also be shown for other measures: Children with high agreeableness and high verbal intelligence were significantly more likely to wait for the delayed gummy bears. In contrast to the group of mothers, we were unable to find any interaction effects in the categorical variable of education × variables of interest. However, there might be only marginal educational differences between preschoolers and schoolchildren since education was a dichotomous variable. Further, when controlling for age, education might not show any effect, as age and education significantly correlated.

Mothers with high education and low agreeableness preferred delayed hypothetical monetary rewards significantly more often. Given our findings, we assume that high education might compensate for low agreeableness. In fact, our findings strongly support Miller et al. (2008), who emphasized that agreeableness "is a prime candidate for further exploration" (p. 163) in DD research.

Limitations and Implications for Future Studies

As the present study measured DoG and DD using a cross-sectional design, it is impossible to draw any conclusions on causal effects. The present study included primary and secondary reinforcers. However, the experimental design could have included both primary and secondary reinforcers for mothers and children, but when the study was conducted in 2008, there was a lack of experimental measures for DoG using different rewards such as food. The recently published Delay of Gratification Test for Adults (DoG-A; Forstmeier et al., 2011) includes primary (e.g. food) and secondary (e.g., money) rewards.

To sum up, the exploration of factors explaining individual differences in DoG and DD is of the greatest relevance, as high DoG or low DD seems to buffer against Attention-Deficit Hyperactivity Disorder (Barkley, 1997; Byrne, DeWolfe, & Bawden, 1998; Schweitzer & Sulzer-Azaroff, 1995) and obesity in children (Seeyave et al., 2009) as well as obesity (Weller et al., 2008), psychopathology (Krueger et al., 1996), Borderline Personality Disorder (Ayduk et al., 2008), alcohol and drug abuse in adults (Baumeister & Heatherton, 1996; de Wit, 2009).

Future studies should consider verbal intelligence, education, and agreeableness for the examination of individuals' differences in self-regulation. Additionally, future studies could include further measures of cognition, e.g. tests of working memory. In conclusion, DoG and DD studies in children and adults should prefer measures of verbal over fluid intelligence.

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Paper 3: Structural Brain Differences between Elderly Individuals with Low versus High Delay of Gratification

(Drobetz, Hänggi, Maercker, Kaufmann, Jäncke, & Forstmeier, submitted)

Abstract

Delay of gratification (DoG) refers to the ability to postpone immediate rewards in favor of later and better rewards; for example, to hold out for two marshmallows later instead of taking one marshmallow now. Delay Discounting (DD), a DoG-related concept, has been linked to smaller inferolateral and dorsolateral prefrontal cortex (DLPFC) gray matter (GM) volumes. The main aim of the present study was to determine structural brain differences between individuals with low and high DoG using structural magnetic resonance imaging and surface-based morphometry to investigate cortical thickness. The behavioral Delay of Gratification Test for Adults was used to distinguish 20 delayers from 20 non-delayers (age ≥ 63 years). Relative to non-delayers, delayers showed significantly increased cortical thickness in bilateral DLPFC regions and in the left anterior cingulate gyrus and sulcus. Further, delayers had significantly larger GM volumes in the striatum. In conclusion, DoG in old age is associated with structural changes in areas of the reward system as well as in cortical projection areas of dopaminergic neurons (e.g., DLPFC). Moreover, the study extends previous findings on DD and serves as basis for further investigations in motivation.

Keywords: delay of gratification, delay discounting, impulsivity, elderly, surface-based morphometry, dorsolateral prefrontal cortex

Introduction

Throughout the lifespan, people constantly have to decide between immediate and delayed rewards. Walter Mischel's well-established concept of delay of gratification (DoG) describes the voluntary postponement of immediate smaller for later better rewards (Mischel et al., 1989)—for example, holding out for two marshmallows later instead of taking one marshmallow now. DoG is a multidimensional construct comprising aspects of self-control (Metcalfe & Mischel, 1999), foresight (Eack et al., 2008), and impulsivity (e.g., Monterosso & Ainslie, 1999). For example, impulsivity can be defined as engaging in behavior without sufficient consideration of its consequences, resulting in actions lacking in foresight (Moeller et al., 2001), which nicely describes the nature of low DoG.

Numerous studies have explored DoG in children, as well as the positive long-term outcomes of high DoG or the negative consequences of low DoG in childhood and adolescence (e.g., Krueger et al., 1996; Mischel et al., 1989; Shoda et al., 1990). More recently, DoG has also been studied in samples of adults (Knolle-Veentjer et al., 2008) and in the elderly (Forstmeier et al., 2011). Although DoG continues to play a major role in old age—for example, older adults with diabetes have to resist the temptation of sweets and cakes, and regular exercise is needed to prevent or reduce physical problems in late life—behavioral and imaging studies of DoG in elderly populations are still scarce. Thus, after decades of research focusing on DoG in children, it is now of utmost relevance to elucidate the neuronal underpinnings of DoG in older people.

Delay discounting (DD) has received more research attention because its measurement is far less complex. DD can be defined as the decrease in the subjective value of a gratification as a function of the time to its delivery (Kirby & Maraković, 1996; Klapproth, 2008). Specifically, people would tend to choose $200 in 20 weeks over $190 in 19 weeks, but they would choose $190 immediately rather than $200 in a week's time (Herrnstein, 1990). The longer the delay interval, the more likely an individual is to choose the immediate incentive (Simon et al., 2008). As low DD reflects higher self-control, DoG and DD correlate negatively. DD behavior has been reported not only in humans, but also in pigeons (Ainslie, 1974) and rats (Reynolds et al., 2002; Simon et al., 2008).

Although DoG and DD are clearly related constructs, there are some fundamental differences between them (Drobetz et al., 2012; Reynolds & Schiffbauer, 2005). DD is a more cognitive and learning-mediated process than DoG and calls for unchangeable and separate commitment choices on each trial. In contrast, DoG involves sustained choices: individuals have to overcome the temptation at hand (e.g., a cookie) and to sustain their choice of the delayed reward over the delay period (Green et al., 1994).

Reward research differentiates between primary rewards (e.g., food, water, or sexual stimuli) and secondary rewards (e.g., money or cultural goods). Primary rewards or reinforcers are evolutionarily innate and indispensable as they enable survival and reproduction. Whereas primary rewards generally reinforce behavior without being learned, secondary rewards gain in importance via learning-mediated processes and through their association with primary rewards (Walter et al., 2005). The findings published to date indicate that healthy individuals show higher DD for primary reinforcers such as food and alcohol than for secondary reinforcers such as money (Forzano & Logue, 1992; Kirby & Guastello, 2001; Odum & Rainaud, 2003; Petry, 2001)—possibly because food and drinks are perishable. Whereas money retains its value over time (disregarding inflation), the value of food and other primary rewards decreases over time (Odum & Rainaud, 2003). As primary reinforcers are essential and enable survival (Walter et al., 2005), moreover, people may be more likely to choose immediate rewards in this context.

Interestingly, to our knowledge, there have to date been no structural magnetic resonance imaging (sMRI) studies of the specific behavioral construct of DoG. However, sMRI and functional MRI (fMRI) have been used to investigate the structural correlates and activation patterns of DD. There are several possible explanations for the lack of MRI studies on DoG. First, DoG studies in adults and in the elderly are generally scarce, as an appropriate measure has only recently been developed. The Delay of Gratification Test for Adults (Forstmeier et al., 2011) adapts the classical "marshmallow paradigm" (Mischel, 1974) to enable the valid and reliable behavioral measurement of DoG in adults. Second, using real rewards such as money or food is more complex and expensive than is using hypothetical monetary choice procedures, which are more easily applied in imaging studies.

Behavioral and imaging studies on DoG in older adults are of utmost relevance as research has shown that high DoG is a significant predictor of wellbeing in the elderly (Forstmeier et al., 2011). Consistent findings from imaging studies suggest that DD, impulsivity, and related constructs are associated with the dorsolateral prefrontal cortex (DLPFC), the orbitofrontal cortex (OFC), the anterior cingulate cortex (ACC), and the striatum (e.g., Bjork et al., 2009; Matsuo et al., 2009; McClure et al., 2004). A structural MRI study measuring DD in healthy adults aged between 20 and 58 years showed the following: On the one hand, higher DD correlated significantly with smaller inferolateral and DLPFC gray matter (GM) volumes. On the other hand, DD did not correlate significantly with orbitofrontal or mesofrontal GM density, total cerebral volume, or total intracranial volume (Bjork et al., 2009). There have to date been no DD imaging studies with adults aged 60 and older. Voxel-based morphometry (VBM) in individuals with schizophrenia revealed significant positive correlations between foresight and GM volume in the right OFC, left ventromedial prefrontal, and posterior and anterior cingulate cortices. Additionally, GM in the right OFC and ventromedial prefrontal cortex was a significant predictor of better foresight (Eack et al., 2008). A VBM study in individuals aged between 19 and 65 years who self-rated their impulsiveness on the Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995) confirmed the patterns described above: Lower right and left OFC GM volumes correlated significantly with higher impulsivity (Matsuo et al., 2009). Additionally, GM volumes of the left ACC were marginally significantly (p = 0.05) associated with impulsivity. In detail, the GM volume of the right medial OFC was significantly negatively correlated with the non-planning impulsivity subscale of the BIS-11. On the other hand, left OFC GM volumes were significantly inversely correlated with the motor impulsivity subscale of the BIS-11 (Matsuo et al., 2009).

In short, two separate systems modulate decisions between immediately available and delayed rewards. In general, decisions between immediate and delayed rewards involve the right and left intraparietal cortex, the right DLPFC, the right ventrolateral prefrontal cortex (McClure et al., 2004), the ventromedial prefrontal cortex (Pedroni, Koeneke, Velickaite, & Jäncke, 2011), and the right lateral OFC, irrespective of the choice made (McClure et al., 2004). Higher risk-taking behavior is linked with less neuronal activation in the left anterior lateral prefrontal cortex (Jäncke et al., 2008). Transcranial direct current stimulation of the DLPFC decreased impulsivity (Beeli, Casutt, Baumgartner, & Jancke, 2008; Beeli, Koeneke, Gasser, & Jancke 2008). In a repetitive transcranial magnetic stimulation study, males were significantly riskier in decision-making after disruption of the right DLPFC (Knoch et al., 2006). Further, the transient disruption of the left prefrontal cortex resulted in individual's significantly higher preference for immediate reinforcers (Figner et al., 2010).

Choices for immediate monetary rewards involve activation in the ventral striatum, the medial prefrontal cortex (PFC), and the OFC—that is, areas belonging to the classic limbic system including the paralimbic cortex. In contrast, choices for delayed rewards involve activation in the frontal and parietal regions. This system may inhibit the impulse to take the immediate gratification or may weigh up prospective benefits (via abstract reasoning or imagery; (McClure et al., 2004).

In an fMRI study, McClure et al. (2007) used fruit juice and water as primary reinforcers. The results were consistent with their previous findings on monetary rewards (with gift certificates as secondary reinforcers): Activation in the limbic system was higher for decisions between immediate and delayed drinks than for decisions between two delayed primary reinforcers. Further, decisions between immediate and delayed drinks as well as between two delayed drinks recruited the lateral PFC and the posterior parietal cortex (McClure et al., 2007).

The main aim of the present pioneering sMRI study in DoG was to determine whether there were structural brain differences between individuals with low and high DoG. Given previous findings on DD and impulsivity, we expected to find differences in cortical thickness in the prefrontal cortex as well as volumetric differences in subcortical structures associated with the reward system (e.g., the striatum and nucleus accumbens). Specifically, we hypothesized that individuals with high DoG (delayers) would have increased cortical thickness in the prefrontal cortex than would individuals with low DoG (non-delayers). In addition, we hypothesized that delayers would have increased GM volumes in the striatum and nucleus accumbens than would non-delayers. Given the findings of higher DD for primary reinforcers, we predicted larger clusters of cortical thickness differences when DoG involved primary reinforcers than when it involved secondary reinforcers.

Materials and Methods

Participants

We recruited 40 participants from a DoG study of 120 cognitively unimpaired older individuals. Inclusion criteria for the present MRI study were lack of cognitive impairment (score of ≥ 26 on the Mini Mental State Examination [(MMSE; Folstein, Folstein, & McHugh, 1975) and age of ≥ 60 years. Exclusion criteria were current mental health disorders, neurological disorders, and history of stroke or dementia. In total, 42 individuals participated; however, two participants had to be excluded as one reported a history of apoplexy and one was taking Ritalin for Attention Deficit Hyperactivity Disorder (ADHD). Thus, the total sample consisted of 40 older adults between 63 and 93 years. Participants were divided into two subgroups according to their DoG-A score (20 delayers vs. 20 non-delayers); the groups were matched according to sex, age, and education. All participants were native Swiss-German or German speakers. The study was approved by the Ethics Committee of the canton of Zurich, Switzerland. We obtained written informed consent from all participants and paid them CHF 100 for their willingness to participate.

Behavioral Measures

We measured DoG using the Delay of Gratification Test for Adults (DoG-A; Forstmeier et al., 2011), a behavioral measure of self-motivation specifically designed for adults and older individuals (see Forstmeier et al., (2011) for a detailed description). The test requires participants to make 18 choices between immediate smaller and delayed larger primary and secondary reinforcers: snacks, hypothetical money, real money, and magazines. For instance, in the snacks subscale, the experimenter asks the participant to decide between 1 piece of chocolate immediately and 2 pieces in 2 hours. In the real money subscale, the participant has to decide between CHF 8 now or CHF 10 in 1 month.

Whereas the snacks and hypothetical money subscores range from 0 to 8, the real money and magazines subscores are dichotomous. A composite DoG score was calculated by first dichotomizing the two continuous variables (snacks and hypothetical money) and then summing all four subscores. We used the DoG-A composite score to distinguish delayers from non-delayers as previous findings suggest that there are no differences in activation patterns between primary and secondary reinforcers (McClure et al., 2007).

As the snacks subscore showed the most consistent pattern of results in a validation study of the DoG-A—i.e., moderate positive correlations with self-reported motivation regulation, optimism, dutifulness, deliberation, and wellbeing (Forstmeier et al., 2011)—we also report the correlations between DoG in the snacks subscale and cortical thickness separately.

The intercorrelations of the subscales were low to medium, indicating relative domain independence of the four reward types (see Chapman, 1996). Whereas the internal consistency (Cronbach's α = .39) of the composite score was moderate, its criterion validity provided strong support for the operationalization of the DoG-A. Specifically, the DoG-A composite score and the general DD rate correlated significantly (r = -.43, p < .05). In addition, there was a significant correlation between the DoG-A composite score and motivation regulation, a DoG-related concept (r = .20, p < .05).

Magnetic Resonance Imaging: Data Acquisition

Magnetic resonance imaging (MRI) scans were acquired on a 3.0 T Philips Achieva whole body scanner (Philips Medical Systems, Best, The Netherlands) equipped with a transmit-receive body coil and a commercial eight-element sensitivity encoding (SENSE) head coil array. Two volumetric 3D T1-weighted gradient echo sequence (fast field echo) scans were obtained from all 40 participants. Slices were acquired in the sagittal plane with a measured and reconstructed spatial resolution of $0.94 \times 0.94 \times 1.00$ mm (matrix 256×256 pixels, 160 slices). Further imaging parameters were: field of view FOV = 240×240 mm, echo time TE = 3.7 ms, repetition time TR = 8.06 ms, flip angle $\alpha = 8°$, and SENSE factor SF = 2.1. Scantime was about 8 min. per scan. T2-weighted images were also acquired to exclude any T2-sensitive tissue anomalies. In addition, we acquired diffusion-weighted images as well as a resting state fMRI sequence, the results of which are not part of the present study.

Surface-based Morphometry and Subcortical Segmentation

Cortical surface reconstruction and volumetric segmentation was performed with the FreeSurfer image analysis suite, which is documented and freely available for download online (http://surfer.nmr.mgh.harvard.edu/). The technical details of these procedures are described in prior publications (Dale, Fischl, & Sereno, 1999; Fischl & Dale, 2000; Fischl, Liu, & Dale, 2001; Fischl et al., 2002; Fischl, Salat, et al., 2004; Fischl, Sereno, & Dale, 1999; Fischl, Sereno, Tootell, & Dale, 1999; Fischl, van der Kouwe, et al., 2004). Briefly, the two 3D structural T1-weighted MRI scans were realigned, averaged, and then used to construct models of each subject's cortical surface to measure brain features such as cortical thickness. This is a fully automated procedure involving segmentation of the cortical white matter (WM) (Dale et al., 1999), tessellation of the GM/WM junction, inflation of the folded surface tessellation patterns

(Fischl, Sereno, & Dale, 1999) and automatic correction of topological defects in the resulting manifold (Fischl et al., 2001). This surface was then used as the starting point for a deformable surface algorithm designed to find the gray/white and pial (GM/cerebrospinal fluid) surfaces with submillimeter precision (Fischl & Dale, 2000). The procedures for measuring cortical thickness have been validated against histological analysis (Rosas et al., 2002) and manual measurements (Kuperberg et al., 2003; Salat et al., 2004). This method uses both intensity and continuity information from the surfaces in the deformation procedure in order to be able to interpolate surface locations for regions in which the MRI image is ambiguous (Fischl & Dale, 2000). For each subject, the thickness of the cortical ribbon was computed on a uniform grid (comprised by vertices) with 1 mm spacing across both cortical hemispheres, with the thickness being defined by the shortest distance between the gray/white and pial surface models. The thickness maps produced are not limited to the voxel resolution of the image and are thus sensitive to submillimeter differences between groups (Fischl & Dale, 2000). Thickness measures were mapped to the inflated surface of each participant's brain reconstruction, allowing data to be visualized across the entire cortical surface (i.e., gyri and sulci) without being obscured by cortical folding. Each subject's reconstructed brain was then morphed to an average spherical surface representation that optimally aligned sulcal and gyral features across subjects (Fischl, Sereno, & Dale, 1999). This procedure provides accurate matching of morphologically homologous cortical locations among participants on the basis of each individual's anatomy, while minimizing metric distortions. This transform was used to map the thickness measurements into a common spherical coordinate system. Data were resampled for all subjects into a common spherical coordinate system (Fischl, Sereno, & Dale, 1999). The data were then smoothed on the surface tessellation using an iterative nearest-neighbour averaging procedure (equivalent to applying a two-dimensional Gaussian smoothing kernel along the cortical surface with a full width at half maximum of about 15 mm). In addition, we calculated global brain measures such as intracranial volume, total GM volume, total WM volume, and mean cortical thickness.

Statistical Analyses

General linear models (GLM) were applied to the surface-based morphometric maps using FreeSurfer (mri_glmfit) and to the behavioral, volumetric subcortical, and global brain measures using IBM SPSS (version 19). We used independent sample *t* tests to compare the delayers with the non-delayers with respect to regional cortical thickness and behavioral and global brain measures. We compared the subcortical volumes using analysis of covariance models with total intracranial volume as covariate of no interest. Differences between the two groups with respect to regional cortical thickness were thresholded with a height threshold of $p < 0.01$ (uncorrected for multiple comparisons) and an extent threshold of $k = 30$ vertices. In terms of regional, cortical measurements, due to our strong a priori hypotheses, we focused on the dorsolateral and ventromedial PFC, the orbitofrontal cortex, and the cingulate cortex. The peak coordinates of the clusters reported are in Montreal Neurological Institute (MNI) stereotactic space.

For the analysis of the snacks subscale (primary reinforcers), we used correlations between the total snacks subscore and cortical thickness, as the DoG-A snacks subscore is a continuous scale ranging from 0 to 8 (see Forstmeier et al., 2011). Of course, delayers had significantly higher scores on the snacks subscale ($M = 7.25$, $SD = 1.06$) than did non-delayers ($M = 3.10$, $SD = 3.08$), $t(38) = -5.70$, $p < 0.001$ (two-tailed), $d = 1.85$.

Results

Demographics and Global Brain Measures

The characteristics (demographics, cognitive status, verbal intelligence, and global brain tissue parameters) of the two subgroups are reported in Table 7. There were no significant differences between delayers and non-delayers in any of the demographic variables (e.g., age, education, etc.), in cognitive status (Mini Mental State Examination; Folstein et al., 1975), or in total intracranial volume (ICV), total GM volume, total WM volume, or mean global cortical thickness. The non-delayers chose immediate gratification significantly more often than did the delayers ($p < 0.001$).

Table 7 Demographic and Behavioral Characteristics and Global Brain Measures of Delayers and Non-delayers

Variable	Delayers (*n* = 20)	Non-delayers (*n* = 20)	
	Mean ± SD (range)	Mean ± SD (range)	*p*
Age	74.5 ± 8.5 (63–92)	72.9 ± 7.0 (64–93)	0.52
Gender	12 female (60.0%)	14 female (70.0%)	0.51
Education (years)	12.5 ± 1.8 (9–18)	13.1 ± 2.7 (10–20)	0.46
Verbal intelligence	34.0 ± 3.0 (27–40)	35.1 ± 2.1 (31–38)	0.19
Number of right handers	18 (90.0%)	18 (90.0%)	1.00
MMSE	29.2 ± 1.3 (26–30)	29.5 ± 0.7 (28–30)	0.46
DoG-A	3.0 ± 0.9 (2–4)	0.6 ± 0.5 (0–1)	< .001
ICV (cm^3)	1313.5 ± 239.5 (1002.6–1986.2)	1383.9 ± 242.6 (960.4–1905.9)	0.36
TGMV (cm^3)	558.5 ± 57.4 (468.8–697.9)	556.0 ± 52.6 (451.9–670.6)	0.89
TWMV (cm^3)	219.2 ± 32.8 (161.3–300.2)	223.8 ± 28.1 (181.3–288.3)	0.78
Mean cortical thickness (mm)	2.4 ± 0.1 (2.3–2.6)	2.3 ± 0.1 (2.2–2.6)	0.42

Note. MMSE = Mini Mental State Examination (Folstein et al., 1975), DoG-A = Delay of Gratification Test for Adults – composite (Forstmeier et al., 2011), ICV = intracranial volume, TGMV = total gray matter volume, TWMV = total white matter volume.

Verbal intelligence was measured by the German vocabulary test (Schmidt & Metzler, 1992). We used two-tailed *t* tests for group comparisons of age, education, MMSE, DoG-A composite score, TICV, TGMV, and TWMV and χ^2 tests for group comparisons of gender and handedness.

Cortical Structures

Table 8 summarizes the results for the significant clusters of cortical structures. Compared with non-delayers, the delayers showed significantly increased cortical thickness in the left superior frontal sulcus, the left medial and anterior cingulate gyrus and sulcus (anterior cingulate cortex, ACC), the right cuneus, the right precuneus, the right intraparietal sulcus, the right inferior frontal sulcus, and the right paracentral gyrus and sulcus. In addition, data analysis revealed one cluster indicating significantly increased cortical thickness in the left superior frontal gyrus in non-delayers (Figure 1).

Table 8 Clusters with Cortical Thickness Differences between Delayers and Non-delayers (based on the DoG-A composite score)

Region	Hem.	MNI coordinates x	y	z	Number of vertices	Area (mm^2)	*t* (df = 38)	*r*	*d*
Superior frontal gyrus	left	-8	53	-9	97	83.48	2.65**	0.40	0.86
Superior frontal sulcus	left	-23	14	47	34	20.58	2.62**	0.39	0.85
Cingulate gyrus and sulcus	left	-12	20	29	69	30.54	2.61**	0.39	0.84
Cuneus	right	7	-95	13	1165	841.55	5.03***	0.65	1.72
Precuneus	right	8	-64	51	342	140.45	4.64***	0.60	1.51
Intraparietal sulcus	right	36	-67	39	274	132.05	3.12**	0.45	1.02
Intraparietal sulcus	right	31	-51	42	201	75.66	2.86**	0.42	0.93
Inferior frontal sulcus	right	40	18	35	105	54.32	2.78**	0.41	0.90
Paracentral gyrus and sulcus	right	6	-20	62	135	57.55	2.71**	0.40	0.88

**$p < 0.01$, ***$p < 0.001$

Note. Hem. = hemisphere, MNI = Montreal neurological institute, df = degrees of freedom, *r* = correlation, *d* = effect size calculated using $d = 2r/\sqrt{(1-r^2)}$.

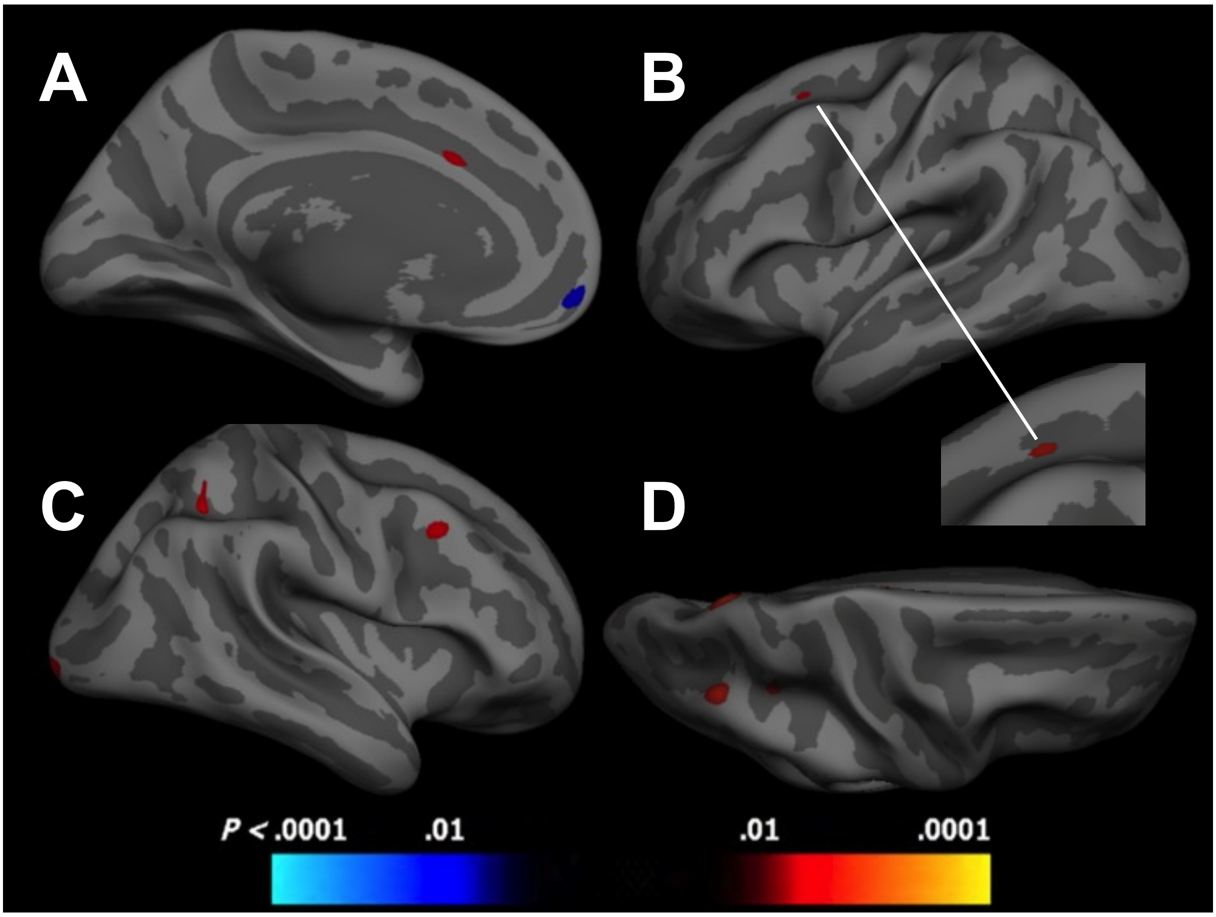

Figure 1 Clusters with cortical thickness differences between delayers and non-delayers
Red-yellow clusters indicate increased cortical thickness in delayers compared with non-delayers and blue-light blue clusters indicate decreased cortical thickness in delayers compared with non-delayers.
A = left medial hemisphere, B = left lateral hemisphere, C = right lateral hemisphere, D = top view.

Subcortical Structures

The results of the analysis of subcortical structures are presented in Table 9. Delayers had a significantly larger GM volume in the left caudate nucleus (mean ± standard deviation: 3.31 ± 0.6 cm^3) than did non-delayers (3.14 ± 0.4 cm^3; $F(1,40) = 3.45$; $p = 0.04$). Although the analysis of covariance (adjusted for total intracranial volume) demonstrated that delayers had a larger GM volume in the right nucleus accumbens and the right caudate nucleus than did non-delayers, the differences were only marginally significant. In detail, delayers (5.59 ± 0.1 cm^3) had a larger GM volume in the right nucleus accumbens than did non-delayers (5.18 ± 0.9 cm^3; $F(1,40) = 1.76$; $p = 0.09$). Further, delayers (3.29 ± 0.5 cm^3) had a larger GM volume in the right caudate nucleus than did non-delayers (3.17 ± 0.4 cm^3; $F(1,40) = 2.23$; $p = 0.07$). There were no significant differences between the two subgroups with respect to the volumes of the hippocampus, the amygdale, or the putamen.

Table 9 Volume Differences in Subcortical Structures between Delayers and Non-delayers (based on the DoG-A composite score)

		Delayers	Non-delayers		
Region	Hem.	Volume (cm^3), M ± SD	Volume (cm^3), M ± SD	F (df = 1)	p
Hippocampus	left	3.51 ± 0.6	3.59 ± 0.5	0.26	0.31
Hippocampus	right	3.58 ± 0.7	3.68 ± 0.5	0.19	0.33
Amygdala	left	1.45 ± 0.2	1.55 ± 0.2	1.47	0.12
Amygdala	right	1.56 ± 0.3	1.61 ± 0.3	0.08	0.39
Nucleus accumbens	left	4.01 ± 0.1	4.13 ± 0.2	0.04	0.42
Nucleus accumbens	right	5.59 ± 0.1	5.18 ± 0.1	1.76	0.09
Putamen	left	4.83 ± 0.7	4.71 ± 0.5	0.71	0.26
Putamen	right	4.45 ± 0.5	4.41 ± 0.6	0.10	0.45
Caudate nucleus	left	3.31 ± 0.5	3.14 ± 0.4	3.46	0.04
Caudate nucleus	right	3.29 ± 0.5	3.17 ± 0.4	2.23	0.07

Note. Hem. = Hemisphere, df = degrees of freedom, M = mean, SD = standard deviation. Analysis of covariance models were applied with delayers and non-delayers as between-subject factor, absolute volumes of subcortical structures as within-subject factor, and intracranial volume as a covariate of no interest.

Results of the Snacks Subscale (Primary Reinforcer)

Table 10 shows the correlations between cortical thickness and DoG as measured by the DoG-A snacks subscale. The primary reinforcer led to larger clusters in OFC areas (Figure 2).

Table 10 Clusters with Cortical Thickness Differences between Delayers and Non-delayers (based on the DoG-A snacks subscale)

Region	Hem.	MNI coordinates x	y	z	Number of vertices	Area (mm^2)	*t* (df = 38)	*r*	*d*
Superior frontal gyrus	left	-8	62	4	603	416.74	2.89**	0.42	0.94
Central sulcus	left	-53	-5	32	411	165.60	3.44***	0.49	1.12
Middle frontal sulcus	left	-23	54	4	94	76.59	2.89**	0.42	0.94
Precuneus	left	-10	-49	56	58	22.50	2.62**	0.39	0.85
Fusiform gyrus	left	-28	-63	-9	50	30.34	2.59**	0.39	0.84
Precuneus	right	8	-66	50	316	131.72	3.98***	0.54	1.29
Paracentral gyrus and sulcus	right	6	-20	66	268	79.18	2.93**	0.43	0.95
Fusiform gyrus	right	31	-39	-14	187	94.50	2.92**	0.43	0.95
Inferior parietal gyrus	right	56	-45	29	140	72.66	2.89**	0.94	0.42

**$p < 0.01$, ***$p < 0.001$

Note. Hem. = hemisphere, MNI = Montreal neurological institute, df = degrees of freedom, r = correlation, d = effect size calculated using $d = 2r/\sqrt{(1-r^2)}$.

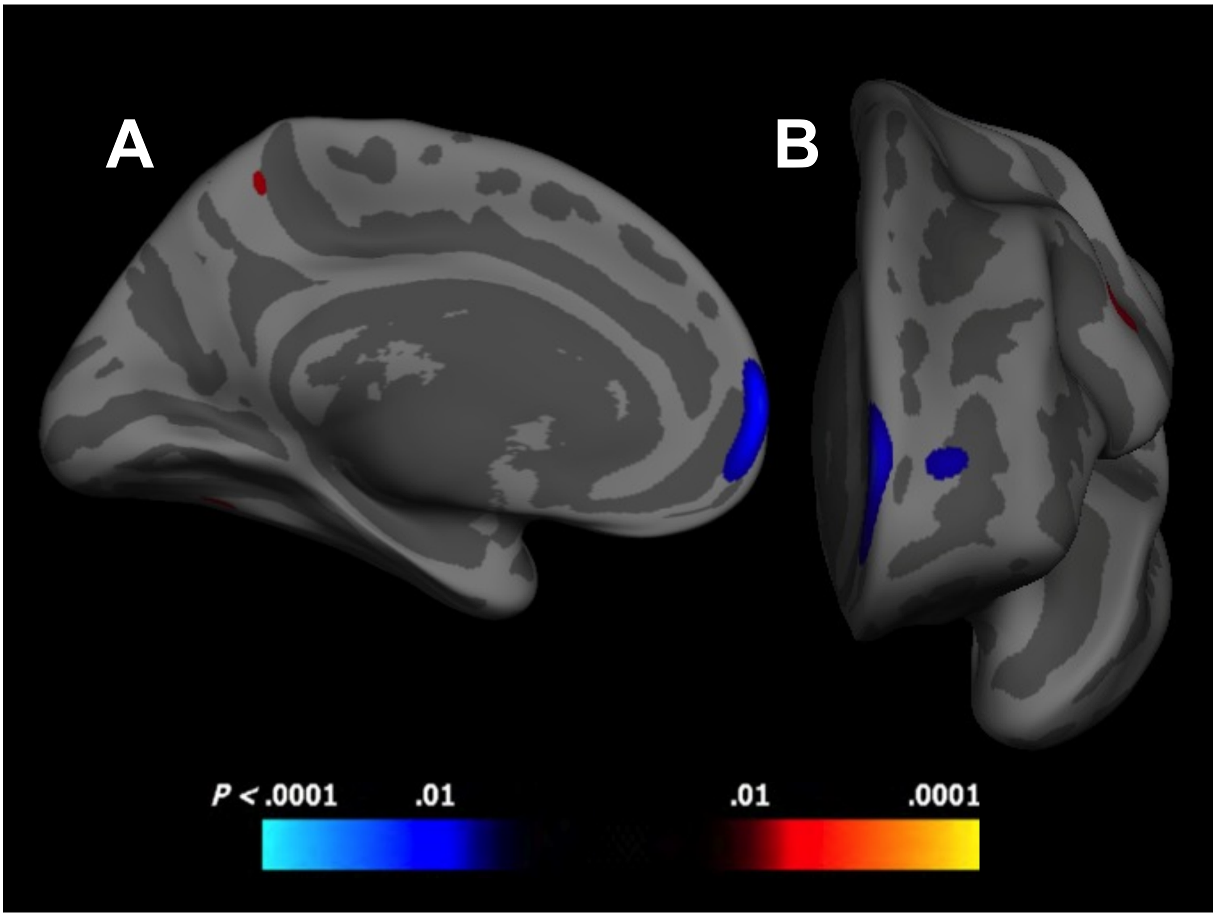

Figure 2 Orbitofrontal cortex regions: Clusters with cortical thickness differences between delayers and non-delayers

Red-yellow clusters indicate increased cortical thickness in delayers compared with non-delayers and blue-light blue clusters indicate decreased cortical thickness in delayers compared with non-delayers.

A = left medial hemisphere, B = front view (left hemisphere).

Discussion

The aim of the present study was to determine morphological brain differences between elderly individuals with high and low DoG. Delayers showed significant increased cortical thickness in the left superior frontal sulcus and in the right inferior frontal sulcus. Thus, account taken of methodological differences, our results are in line with previous findings on DD showing that individuals with low DD (i.e., high self-control) have significantly higher GM volumes in the DLPFC (Bjork et al., 2009). Although there are differences between DoG and DD on the behavioral level, the DLPFC might be associated with both constructs on the neural basis.

In general, the DLPFC is a key area for the control of various behavioral aspects such as top-down and bottom-up control of attention, motor behavior, egocentric orientation, working memory, presence (Jäncke et al., 2009) or emotion regulation (Davidson et al., 2000), risk taking behavior (Jäncke et al., 2008), and further, the DLPFC is seen as modulator of the network associated with behavioral psychological functions (Jäncke et al., 2009). Concretely, both the DLPFC and the striatum play a crucial role in reward processing and in deciding between immediate and delayed rewards, as has previously been shown in both humans and primates (Elliott, Newman, Longe, & Deakin, 2003; Wallis & Miller, 2003). Specifically, McClure et al. (2007) reported increased activity in the DLPFC in individuals making DD choices. Increased activity in the DLPFC has also been shown in the context of complex decision making processes involving unclear delayed or gratification contingencies (Christakou, Brammer, Giampietro, & Rubia, 2009; McClure et al., 2004). In addition, the DLPFC is critical in temporal delays and is highly important for foresight, regardless of the context of rewards as well as for impulsivity and risky behavior (Jäncke et al., 2008). Above all, neurons of the prefrontal cortex, linked with goal-directed behavior, encode reinforcers (Duncan, Emslie, Williams, Johnson, & Freer, 1996; Tremblay & Schultz, 1999). Cognitive control processes such as working memory and exertion of control for the pursuit of long-term goals are known to be accompanied by higher activation of the DLPFC (E. K. Miller & Cohen, 2001). As DoG involves the active management of goals (Freund & Baltes, 2002b), we conclude that individuals with increased cortical thickness in the DLPFC may show more efficient goal-directed behavior and be better able to integrate information (past learning experiences, valuation of rewards). As a result, they show significantly higher DoG.

Surprisingly, non-delayers had significantly increased cortical thickness in a cluster of the left OFC. Matsuo et al. (2009) and Yang et al. (2005) report links between smaller prefrontal GM volume and high impulsivity, as measured by the Barratt Impulsiveness Scale (BIS-11; Barratt, 1994). In contrast, Bjork et al. (2009) found no correlations between scores on the BIS-11 and prefrontal GM volume. The BIS, a self-report questionnaire, may capture other facets of DoG than do behavioral DoG measures. Specifically, the BIS-11 covers the three second-order factors of attentional, motor, and nonplanning impulsiveness and does not explicitly tap impulsivity as the inability to postpone rewards, as defined by Monterosso and Ainslie (1999). Among other brain regions, the OFC is associated with value functions of rewards (Cohen & Ranganath, 2005). Lesion studies suggest that the medial OFC is an important neural substrate of subjective valuation and of the choice of delayed over immediate rewards: Both animals (Cardinal, Winstanley, Robbins, & Everitt, 2004; Rudebeck, Walton, Smyth, Bannerman, & Rushworth, 2006; Winstanley, Theobald, Cardinal, & Robbins, 2004) and humans with lesions in the medial OFC show a significantly higher preference for immediate rewards (Sellitto, Ciaramelli, & di Pellegrino, 2010). Nonetheless, our results in unimpaired older adults are not contradictory to these previous findings. In fact, fMRI studies associate OFC activation with subjective value of rewards or alternatives and risky decision making (Hsu et al., 2005; McKell Carter et al., 2010). Larger GM densities in the OFC have been also shown as a consequence of long-term meditation connected with emotion regulation and response control (Luders, Toga, Lepore, & Gaser, 2009). Thus, increased OFC thickness may represent higher subjective valuation of (immediately available) reinforcers.

We found significant differences in regions of the left ACC. This result is consistent with previous findings suggesting that individuals with high impulsivity have smaller left ACC volumes (Matsuo et al., 2009). Moreover, the ACC monitors response conflict (Barch et al., 2001; Botvinick, Braver, Barch, Carter, & Cohen, 2001). Paradigms such as DoG that include immediate rewards cause higher conflict (McClure et al., 2007). Besides, individuals with ADHD and Borderline Personality Disorder suffering from clinically relevant impulsivity have deficits in ACC function as well as decreased ACC GM volumes relative to unimpaired controls (e.g., Carmona et al., 2005; Leyton et al., 2001). Left ACC activation has also been demonstrated in response inhibition (Horn et al., 2003), another facet of DoG (e.g., Reynolds et al., 2002).

Delayers also had a significantly larger GM volume in the left caudate nucleus and a marginally significantly larger GM volume in the right caudate nucleus and the right nucleus accumbens. A larger sample size with increased statistical power would increase the likelihood of significant findings here. Both the caudate nucleus and the nucleus accumbens are components of the dopamingergic reward system (Breiter & Rosen, 1999). The caudate nucleus of the dorsal striatum is crucial in the representation of the subjective value and magnitude of rewards (Delgado, 2007; Knutson, Delgado, & Phillips, 2009). In decision making, the nucleus accumbens (i.e., the ventral part of the striatum) receives inputs from the limbic system and integrates cognitive information from the prefrontal cortex and the hippocampus with affective information from the amygdala (Wagar & Thagard, 2004). Further, the nucleus accumbens contributes to the goal-directed behavior (Meredith et al., 2008) that is necessary for successful DoG (Freund & Baltes, 2002b; Mischel et al., 1989).

The DoG-A involves both primary and secondary rewards. As the snacks subscale proved to be the best measure of DoG on the behavioral level (Forstmeier et al., 2011), the neural correlates of the snacks subscale were analyzed separately in the present study. However, an fMRI study revealed the same activation patterns for primary reinforcers (drinks) and secondary reinforcers (gift certificates) (McClure et al., 2007; McClure et al., 2004). Why did DoG as measured by the snacks subscale show larger clusters in OFC regions? First, food is more sensitive to failures of self-control: Previous studies have reported higher DD in primary reinforcers (food, drinks) than in secondary reinforcers (money) (Forzano & Logue, 1992; Kirby & Guastello, 2001; Odum & Rainaud, 2003; Petry, 2001). Second, the value of a reinforcer and the expectancy of success are the primary influences on DoG decisions (Cohen & Ranganath, 2005; Mischel, 1974). Snacks may have higher value for older individuals than money or magazines (Forstmeier et al., 2011).

One intriguing finding warrants emphasis: As described above, delayers had significantly higher cortical thickness in DLPFC and PFC areas associated with working memory and attention (Cabeza & Nyberg, 2000). Likewise, DoG and DD are strongly linked to attention and working memory. The postponement of an immediate reward for a later, better reward requires cognitive or attentional control or cognitive distraction (allocation of attention) (Eigsti et al., 2006; Mischel, 1974; Mischel et al., 1989; Yates, Lippett, & Yates, 1981).

Further, attention deficit is associated with impulsivity (e.g., Malloy-Diniz, Fuentes, Leite, Correa, & Bechara, 2007). DD and performance on working memory tasks are negatively correlated (Hinson et al., 2003; Shamosh et al., 2008). In fact, DD processes recruit working memory, as individuals have to actively maintain different reward values and points in time when integrating and processing goal-relevant information (Shamosh et al., 2008). Working memory training has been shown to reduce preferences for immediate monetary rewards in stimulant addicts (Bickel et al., 2011). Our findings also support the results of a transcranial magnetic stimulation (TMS) study (Figner et al., 2010), in which repetitive TMS was applied before adult participants decided between earlier but smaller and later but larger hypothetical monetary rewards. The transient disruption of the left PFC resulted in a significantly higher preference for immediate reinforcers (Figner et al., 2010).

Some limitations of the present study warrant discussion. First, delayers had significantly higher cortical thickness in the right cuneus and the right precuneus than non-delayers. We can only speculate about the reasons for these findings in the visual and medial parietal cortex. As the sample consisted of older individuals aged between 63 and 93 years, the differences may be due to visual impairment or eye surgery (e.g., glaucoma, cataract). We were able to control for vision and number of eye surgeries, but these variables did not act as mediators. Second, the groups differed in clusters of the right intraparietal sulcus and the right paracentral gyrus and sulcus. As yet, there are no explanations for these findings. Third, based on the present cross-sectional findings, it is not possible to draw any conclusions about whether the morphological differences identified are the cause or the consequence of low DoG or impulsivity.

Future DoG studies should obtain longitudinal data in order to cast light on any structural changes over time and to elucidate the neural plasticity of DoG-related cortical and subcortical structures. Additionally, sMRI studies could compare structural brain differences in DoG and in DD by assessing both constructs separately. To permit direct comparison of the two constructs, DoG should be the only measure administered in the DoG group and DD the only measure administered in the DD group. Thus, further investigations could involve four subgroups: individuals with high and low DoG and individuals with high and low DD.

The contributions of this study are as follows: First, to the best of our knowledge, this is the first sMRI study in older adults to investigate the structural substrate of DoG. We measured DoG using a recently published and validated behavioral test requiring individuals to choose between immediate and delayed food, real money, hypothetical money, and magazines (DoG-A; Forstmeier et al., 2011). High DoG in childhood is a predictor of various positive outcomes across the lifespan: better social, cognitive, and emotional functioning, higher academic achievement, better self-worth, better coping with stress, lower risk of obesity, less drug abuse, better physical health (Ayduk et al., 2000; Kubzansky, Martin, & Buka, 2009; Mischel et al., 2011; Mischel et al., 1988; Seeyave et al., 2009; Shoda et al., 1990). Deciding between immediate and delayed rewards is also of utmost relevance in old age: DoG correlates with DD, motivation regulation, dutifulness, optimism, and deliberation in the elderly. High DoG for primary reinforcers also predicts self-regulation and wellbeing in older individuals (Forstmeier et al., 2011). Second, the study extends findings from structural MRI studies on the DoG-related constructs of DD and impulsivity. Third, one of the main findings was that delayers had significantly higher cortical thickness in regions of the DLPFC and PFC (Hinson et al., 2003). These regions are associated with attention and working memory (Cabeza & Nyberg, 2000), two capacities crucial for successful and effective DoG (e.g., Hinson et al., 2003; Mischel et al., 2011).

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Disclosure statement

We declare that there are no actual or potential conflicts of interest including any financial, personal, or other relationships with other people or organizations that could inappropriately influence (bias) this work. We have no financial interests in the Delay of Gratification Test for Adults (DoG-A), which is freely available. Please see Forstmeier, et al. (2011) for a description of test design, procedure, and calculation of scores.

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CURRICULUM VITAE

Name: Reinhard Drobetz

Date of birth: September 19th, 1980

Place of birth: Wiener Neustadt, Austria

Nationality: Austrian

Education

01/2009 – 03/2012	**PhD candidate** (doctoral student) Department of Psychology, Psychopathology and Clinical Intervention, University of Zurich, Switzerland Advisors: Prof. Dr. Dr. Andreas Maercker and Dr. Simon Forstmeier
03/2007 – 04/2008	**Postgraduate diploma "Clinical and Health Psychology"** Postgraduate Center, University of Vienna, KlinGes Grade average: 1.0 (with honors) Professional title (Austria): Clinical Psychologist and Health Psychologist On-the-job training at the Teaching & Research Lab of the University of Vienna and at the Caritas Socialis, Vienna, Austria
03/2007	**Diploma in Psychology** (equivalent to M.A. / M.Sc.) Faculty of Psychology, University of Vienna, Austria Grade average: 1.0 (very good, with honors)
10/2000 – 03/2007	**Psychology** University of Vienna, Austria 1st diploma exam with honors
10/1999 – 09/2000	**Civilian Service** "Stadtheim Wr. Neustadt" - residential care home for elderly and demented people (assistance in occupational therapy)
06/1999	**High school diploma** Bundesgymnasium Neunkirchen, Austria Grade average: 1.0 (very good, with honors)

Professional positions and research experience

04/2009 – present	**Fellow / Alumni of the International Max Planck Research School "The Life Course: Evolutionary and Ontogenetic Dynamics (LIFE)"** 3-year research grant from the Jacobs Foundation
01/2009 – 03/2012	**Research assistant** Swiss national Science Foundation funded project "Motivational Reserve as protective factor in mild Alzheimer's dementia (AD) and mild cognitive impairment (MCI)" Department of Psychology, Psychopathology and Clinical Intervention, University of Zurich, Switzerland
01/2009 – 03/2012	**Psychotherapist** (delegated) Cognitive Behavioral Therapy Center for Psychotherapy, University of Zurich, Switzerland
08/2010 – 03/2011	**Project collaborator**: "Dementia study" Caritas Socialis, Vienna, Austria
06/2010 – 08/2010	**Guest research stay** German Institute for Economic Research (DIW Berlin), Socio-Economic Panel Study (SOEP), Grant received for CHF 1500 (Auslands-Kurz-Mentorat of University of Zurich), Advisors: Prof. Dr. C. Katharina Spiess and Prof. Dr. Gert G. Wagner
04/2008 – 12/2008	**Research and teaching assistant (temporary)** Department of Clinical, Biological and Differential Psychology, Faculty of Psychology, University of Vienna, Austria Advisor: o.Univ.-Prof. Dr. Ilse Kryspin-Exner
10/2007 – 03/2008	**Project collaborator**: "Dementia study" Caritas Socialis, Vienna, Austria
08/2007 – 12/2008	**Project collaborator**: "Hyperhidrosis and social phobia" Faculty of Psychology and Medical University of Vienna, Austria
10/2006 – 03/2008	**Student research assistant** Department of Clinical, Biological and Differential Psychology, Faculty of Psychology, University of Vienna, Austria Advisor: o.Univ.-Prof. Dr. Ilse Kryspin-Exner

Publications

a) Peer reviewed articles

Drobetz, R., Maercker, A., & Forstmeier, S. (2012). Delay of gratification in old age: Assessment, age-related effects, and clinical implications. *Aging Clinical and Experimental Research*, *24*, 6-14. doi: 10.3275/8178

Drobetz, R., Maercker, A., Spiess, C. K., Wagner, G. G., & Forstmeier, S. (accepted). Does the apple fall far from the tree? Intergenerational links and maternal antecedents in children's self-regulation from a household study. *Swiss Journal of Psychology*

Forstmeier, S., Drobetz, R., & Maercker, A. (2011). The delay of gratification test for adults: Validating a behavioral measure of self-motivation in a sample of older people. *Motivation and Emotion, 35*, 118-134. doi: 10.1007/s11031-011-9213-1

Drobetz, R., Hänggi, J., Maercker, A., Kaufmann, K., Jäncke, L., & Forstmeier, S. (in revision). Structural brain correlates of delay of gratification in the elderly

Drobetz, R., Maercker, A., Spiess, C. K., Wagner, G. G., & Forstmeier, S. (submitted). Interactions of cognition, education and personality in decisions between immediate and delayed rewards in mothers and their children

Fankhauser, S., Drobetz, R., Mortby, M. E., Maercker, A., & Forstmeier, S. (submitted). The impact of social and motivational resources on depression in individuals with and without cognitive impairment

Fankhauser, S., Mortby, M. E., Drobetz, R., Maercker, A., & Forstmeier, S. (submitted). Social network and cognitive functioning in old age: Self-efficacy as a mediator?

Mortby, M. E., Maercker, A., Drobetz, R., Fankhauser, S., & Forstmeier, S. (submitted). Midlife motivational abilities: A predictor of apathy and depression in Mild Cognitive Impairment and early Alzheimer disease

Drobetz, R., & Kryspin-Exner, I. (2009). Kognitiv-behaviorale und schematheoretische Behandlung eines Klienten mit Paruresis. *Verhaltenstherapie & Verhaltensmedizin, 30,* 516-528.

Drobetz, R., Derntl, B., & Kryspin-Exner, I. (2008). Autobiographisches Gedächtnis und Emotionen: Ich denke, also fühle ich? *Psychologie in Österreich*, 5, 456-463.

(b) Book chapters

Drobetz, R., & Maercker, A. (2012). Sucht und Abhängigkeit am Beispiel Alkohol. In W. Lutz, U. Stangier, A. Maercker & F. Petermann (Hrsg.), *Klinische Psychologie - Intervention und Beratung* (S. 241-271). Göttingen: Hogrefe.

Maercker, A., Drobetz, R., & Forstmeier, S. (2012). Psychische Probleme älterer Menschen: Beratung und Rehabilitation. In W. Lutz, U. Stangier, A. Maercker & F. Petermann (Hrsg.), *Klinische Psychologie - Intervention und Beratung* (S. 273-298). Göttingen: Hogrefe.

Drobetz, R., Maercker, A., & Krampen, G. (2011). Entspannungsverfahren. In G. Meinlschmidt, S. Schneider & J. Margraf (Hrsg.), *Lehrbuch der Verhaltenstherapie. Band 4. Testverfahren und Fragebögen* (S. 37-44). Heidelberg: Springer.

Drobetz, R., & Kryspin-Exner, I. (2011). Fallberichte in der Klinischen Psychologie und Psychotherapie. In B. U. Stetina, O. D. Kothgassner & I. Kryspin-Exner (Hrsg.), *Wissenschaftliches Arbeiten und Forschen in der Klinischen Psychologie* (S. 287-296). Wien: Utb.

Drobetz, R. (2009). Gesundheitspsychologische Online-Research: Ethisch-qualitative Aspekte und konkrete Beispiele. In B. U. Stetina, & I. Kryspin-Exner (Hrsg.), *Gesundheit und Neue Medien. Psychologische Aspekte der Interaktion mit Informations- und Kommunikationstechnologien* (S. 297-319). Wien: Springer.

(c) Oral presentations

Drobetz, R., Maercker, A., & Forstmeier, S. (2011, November). *Delay of gratification in old age: Comparison of individuals with and without cognitive impairment.* Oral presentation at the 64th Annual Scientific Meeting of the Gerontological Society of America (GSA) in Boston, USA.

Steiner, S., & Drobetz, R. (2011, Mai). *Demenzstudie der Caritas Socialis 2010*. Vortrag am 11. Wiener Internationaler, 21. Deutscher, 51. Österreichischer, 6. gemeinsamer Österreichisch-Deutscher Geriatriekongress in Wien, Österreich.

Drobetz, R., Maercker, A., Spiess, C. K., Wagner, G. G., & Forstmeier, S. (2010, October). *Does the apple fall far from the tree? Evidence for intergenerational links in self-regulation from a household study.* Oral presentation at the International Max Planck Research School on the Life Course (LIFE) Fall Academy in Schwanenwerder, Berlin, Germany.

Drobetz, R., Hänggi, J., Fankhauser, S., Maercker, A., & Forstmeier, S. (2010, September). *Bestehen morphologische Gehirnunterschiede zwischen älteren Personen mit hohem und niedrigem Belohnungsaufschub?* Vortrag am 2. Gemeinsamen Kongress der DGGG und SGG in Berlin, Deutschland.

Drobetz, R., Maercker, A., & Forstmeier, S. (2010, September). *Belohnungsaufschub im Alter: Welche Präferenzen bestehen bei Menschen mit MCI, leichter Alzheimer-Demenz und kognitiv-unbeeinträchtigten Personen?* Vortrag am 2. Gemeinsamen Kongress der DGGG und SGG in Berlin, Deutschland.

Drobetz, R., Maercker, A., & Forstmeier, S. (2010, May). *Delay of gratification in old age*. Oral presentation at the International Max Planck Research School on the Life Course (LIFE) Spring Academy (University of Virginia) in Charlottesville, USA.

Drobetz, R., Maercker, A., & Forstmeier, S. (2009, October). *Delay of Gratification Test for Adults (DoG-A): Novel behavioral measure of self-regulation.* Oral presentation at the Third Conference on Non-Cognitive Skills: Acquisition and Economic Consequences in Berlin, Germany.

Drobetz, R., Steiner, S., Slotta-Bachmayr, B., Psota, G., Strotzka, S., & Kryspin-Exner, I. (2009, Mai). *Empirischer Vergleich zwischen NOSGER & MMSE.* Vortrag am 4. gemeinsamen Österreichisch-Deutschen Geriatriekongress in Wien, Österreich.

Steiner, S., & Drobetz, R. (2008, Dezember). *CS-Demenzstudie: Untersuchung zur Anzahl von Demenzerkrankungen und damit zusammenhängende Faktoren.* Vortrag am Gemeinsamen Kongress der DGG/ÖGGG und der DGGG/SG in Potsdam, Deutschland.

Drobetz, R., Derntl, B., & Kryspin-Exner, I. (2008, April). *Geschlechts- und Bildungseffekte beim Abruf autobiographischer Erinnerungen.* Vortrag an der 8. Wissenschaftlichen Tagung der Österreichischen Gesellschaft für Psychologie in Linz, Österreich.

Drobetz, R., Derntl, B., & Kryspin-Exner, I. (2007, July). *Autobiographical Memory (AM): Preclinical standardization of novel stimuli and investigation of AM-specificity considering gender and* education. Oral presentation at the Xth European Congress of Psychology in Prague, Czech Republic.

(d) Poster presentations

Drobetz, R., Maercker, A., Hänggi, J., Jäncke, L., & Forstmeier, S. (May, 2011). *Delay of gratification: Choices between immediate und delayed rewards in old age.* Poster presented at the 23rd Annual Convention of the Association of Psychological Science in Washington, USA.

Drobetz, R., Maercker, A., & Forstmeier, S. (May, 2011). *Delay of gratification in individuals with Mild Cognitive Impairment, mild Alzheimer's dementia and cognitively unimpaired control.* Poster presented at the 4th Annual Meeting of the Society for the Study of Motivation in Washington, USA.

Drobetz, R., Maercker, A., & Forstmeier, S. (Juni, 2011). *Belohnungsaufschub bei Personen mit Mild Cognitive Impairment, leichter Alzheimer-Demenz und kognitiv nicht-beeinträchtigten Kontrollpersonen.* Poster präsentiert am 7. Workshopkongress für Klinische Psychologie und Psychotherapie in Berlin, Deutschland.

Drobetz, R., Steiner, S., Slotta-Bachmayr, B., Hallwirth-Spörk, C., Strotzka, S., & Kryspin-Exner, I. (September, 2010). *Severe Mini Mental State Examination (SMMSE): Validierung der deutschsprachigen Version.* Poster präsentiert am 2. Gemeinsamen Kongress der DGGG und SGG in Berlin, Deutschland.

Drobetz, R., Maercker, A., & Forstmeier, S. (November, 2009). *Delay of gratification in old age.* Poster präsentiert am Kongress der Schweizerischen Gesellschaft für Gerontologie in Fribourg, Schweiz.

Drobetz, R., Maercker, A., & Forstmeier, S. (October, 2009). *Delay of gratification: Evaluation of a model and morphological differences.* Poster presented at the International Max Planck Research School on the Life Course (LIFE) Fall Academy in Ann Arbor, USA.

Drobetz, R., Forstmeier, S., & Maercker, A. (May, 2009). *Model of delay of gratification*. Poster presented at the International Max Planck Research School on the Life Course (LIFE) Spring Academy in Boldern, Switzerland.

Drobetz, R., Derntl, B., & Kryspin-Exner, I. (2008, July). *Standardization of novel questionnaire for autobiographical memory (AM) and evaluation of emotional stimuli*. Poster presented at the XXIX International Congress of Psychology in Berlin, Germany.

Teaching

University of Zurich, Switzerland

02/2012 – 05/2012	Gender und psychische Störungen
09/2011 – 12/2011	Fallbezogenes Lernen in der Psychopathologie
09/2011 – 12/2011	Projektgruppe Klinische Gerontopsychologie
02/2011 – 05/2011	Psychopathologie: Depressive Störungen
09/2010 – 12/2010	Klinische Diagnostik und Fallbezogenes Lernen in der Psychopathologie

University of Vienna, Austria

04/2012 – 06/2012	Basisfertigkeiten der Klinischen und Gesundheitspsychologie
03/2011 – 08/2011	Basisfertigkeiten der Klinischen und Gesundheitspsychologie
11/2009 – 02/2010	Basisfertigkeiten der Klinischen und Gesundheitspsychologie
10/2008 – 12/2008	Vorlesung Klinische Psychologie I
10/2007 – 06/2008	Projektstudium Klinische Psychologie: Entspannungsverfahren, Rechtliche Rahmenbedingungen in der Klinischen Psychologie
03/2007 – 03/2008	Tutorium zum Fachliteraturseminar Klinische Psychologie
10/2006 – 03/2008	Tutorium zur Vorlesung Klinische Psychologie